PRODUCT ENGINEERING

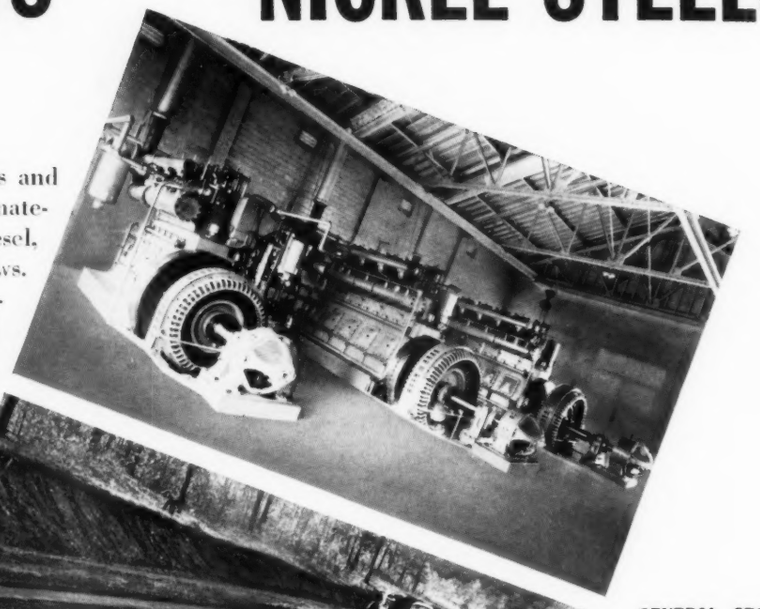
AUGUST, 1939

FOR VITAL DIESEL PARTS THERE ARE APPROPRIATE NICKEL STEELS

Diesel economy—born of high pressures and high temperatures—cruelly tests engine materials. To foresee the useful life of a Diesel, look at its stout heart and bones and sinews.

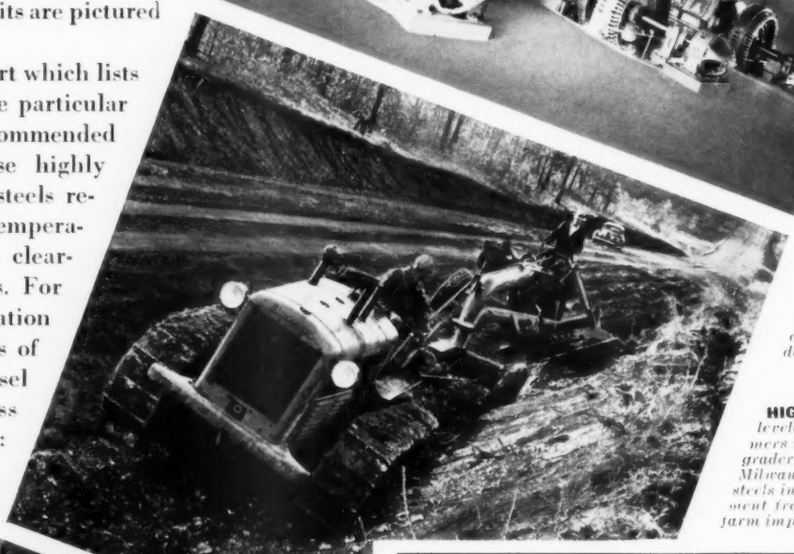
Your safe guide, and safeguard, is liberal use of Nickel alloy steels in *all* vital parts. As is the practice of three leading makers whose Diesel units are pictured on this page.

Look, too, at this chart which lists 25 Diesel parts and the particular Nickel alloy steels recommended to serve best in these highly stressed units. Nickel steels retain strength at high temperatures, maintain close clearances for long periods. For more complete information about other advantages of Nickel alloys in Diesel service, please address your inquiry direct to:

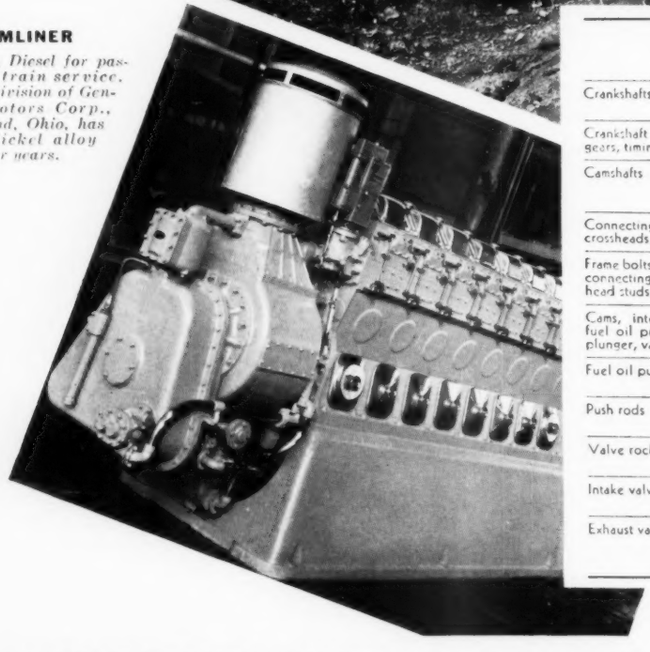


CENTRAL STATION

Three municipal power plant generators driven by 250, 415 and 500 h.p. Worthington Diesels, Worthington Pump & Machinery Co., Harrison, N.J., depends upon Nickel steels.



HIGHWAY... *Mastering mud, levelling hills, this Allis-Chalmers is pulling an experimental grader. Allis-Chalmers Mfg. Co., Milwaukee, Wis., uses Nickel alloy steels in numerous types of equipment from giant turbines to small farm implements.*



STREAMLINER

600 h.p. Diesel for passenger train service. Diesel Division of General Motors Corp., Cleveland, Ohio, has used Nickel alloy steels for years.

PART	SERVICE REQUIREMENTS	STEELS RECOMMENDED	TREATMENT
Crankshafts	Strength, toughness, good fatigue resistance	SAE 4340 SAE 3240	Quenched and tempered
Crankshaft pinions, cam-shaft gears, timing gears	Strength with high wear resistance	SAE 3250	Quenched and tempered
Camshafts	Wear resistant surface, tough core	SAE 2315 SAE 4615 SAE 3115	Casehardened
Connecting rods, piston rods, crossheads, exhaust valve stems	Strength, high toughness and ductility	SAE 2330	Quenched and tempered
Frame bolts, tie rods, stay bolts, connecting rod bolts, cylinder head studs, etc.	Strength, high toughness and ductility	SAE 2330 SAE 3130	Quenched and tempered
Cams, integral, cam rollers, fuel oil pump plunger, valve plunger, valve barrels	High wear resistance with strong and tough core	SAE 3312	Casehardened
Fuel oil pump lever	High wear resistance with strong and tough core	SAE 3215	Casehardened
Push rods	High compressive strength and toughness	SAE 2345	Quenched and tempered
Valve rockers	Strength, high toughness and ductility	SAE 4340 SAE 2330	Quenched and tempered
Intake valves	Moderate strength, resistance to wear and deformation	SAE 3140	Quenched and tempered
Exhaust valves, seats	Resistance to elevated temperatures and to corrosion from exhaust gases	21% Cr, 12% Ni	(Special heat treatment)

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

Engineering
Library

PRODUCT ENGINEERING

VOLUME 10 AUGUST, 1939 NUMBER 8

What's Coming—The problem of aluminum cold pressings versus aluminum hot pressings involves a number of fundamental facts that must be considered when deciding which to use. The lead article in September *Product Engineering* will cover this subject thoroughly including the properties of the materials and the advantages of each of the two types of construction.

Other general articles that will appear in September *P.E.* will include the concluding part of Mr. Cudhea's article on the design of thin sheet stainless steel members, the design of cams made of plastics, the use of rubber molds for casting of small metal parts and the concluding article of the series on chemical coloring by Dr. Young.

In the Modern Designs department the feature presentation will be the details of the electric drives and controls on a new design of grinder.

• • •

Cover Picture—Take-off of one of the six 74-passenger Boeing 314 Pan-American Clippers, off to Europe on one of the June inaugural flights that made passenger air-service to Europe an established fact.

N. O. WYNKOOP, *Publisher*
G. F. NORDENHOLT, *Editor*

JOSEPH KERR, Managing Editor
K. H. CONDIT, Consulting Editor
JOHN SASSO, Assistant Editor
R. D. TOWNE, Assistant Editor
R. R. WIESE, Western Editor
PAUL WOOTON, Washington

W. E. KENNEDY, Manager

Published monthly. Price 35c a copy. Subscription rates—United States, Canada, Mexico, Central and South American countries $3 a year. All other countries, $5 a year or 20 shillings. Entered as second-class matter August 21, 1936, at Post Office, Albany, N.Y., under act of March 3, 1879. Printed in U.S.A. Publication Office, 99-129 North Broadway, Albany, N. Y. Editorial and Executive Offices, 330 West 42d Street, New York, N. Y.

Branch Offices: 520 North Michigan Avenue, Chicago; 883 Mission Street, San Francisco; Aldwych House, Aldwych, London, W. C. 2; Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Atlanta, Ga. Cable Address: MCGRAWHILL, New York. Member A. B. P. Member A. B. C.

COPYRIGHT 1939 BY
McGRAW-HILL PUBLISHING CO., INC.

JAMES H. McGRAW
Founder and Honorary Chairman

JAMES H. McGRAW, JR., President
HOWARD EHRLICH, Executive Vice-President
B. R. PUTNAM, Treasurer
MASON BRITTON, Vice-Chairman
D. C. McGRAW, Secretary
J. E. BLACKBURN, JR., Circulation Manager

Die-Castings or Plastics 320
HERBERT CHASE—Design advantages, properties and relative costs of die-cast and plastic molded parts.

Modern Designs 326
Pictorial presentations of salient design features in a representative group of current-model products and machines.

Koroseal 332
H. E. FRITZ—Properties and characteristics of a new thermoplastic elastic material.

Hydraulic Circuits 336
ALBERT H. DALL—Throttle type and variable displacement pump circuits which are used for controlling rate of feed in machines.

What Is Invention—III 339
H. A. TOULMIN, JR.—Presenting the positive aspects and qualities of new and useful ideas that make an invention patentable.

Furnace Brazed Joints 341
H. H. SCHMITT—Electric furnace brazing as applied to assemblies of non-ferrous parts.

Spot-Welded Structures—I 344
G. G. CUDHEA—Design of spot-welded structures of formed stainless steel sheets.

Liquid-Tight Riveted Joints 348
FRED M. MORRIS—Methods of making liquid-tight riveted joints and seams in fuel tanks and in float and hull constructions.

Helical Spring Tables—I 361
PAUL KLAMP—Beginning a series presenting a quick method for selecting general purpose helical springs.

Editorial 319

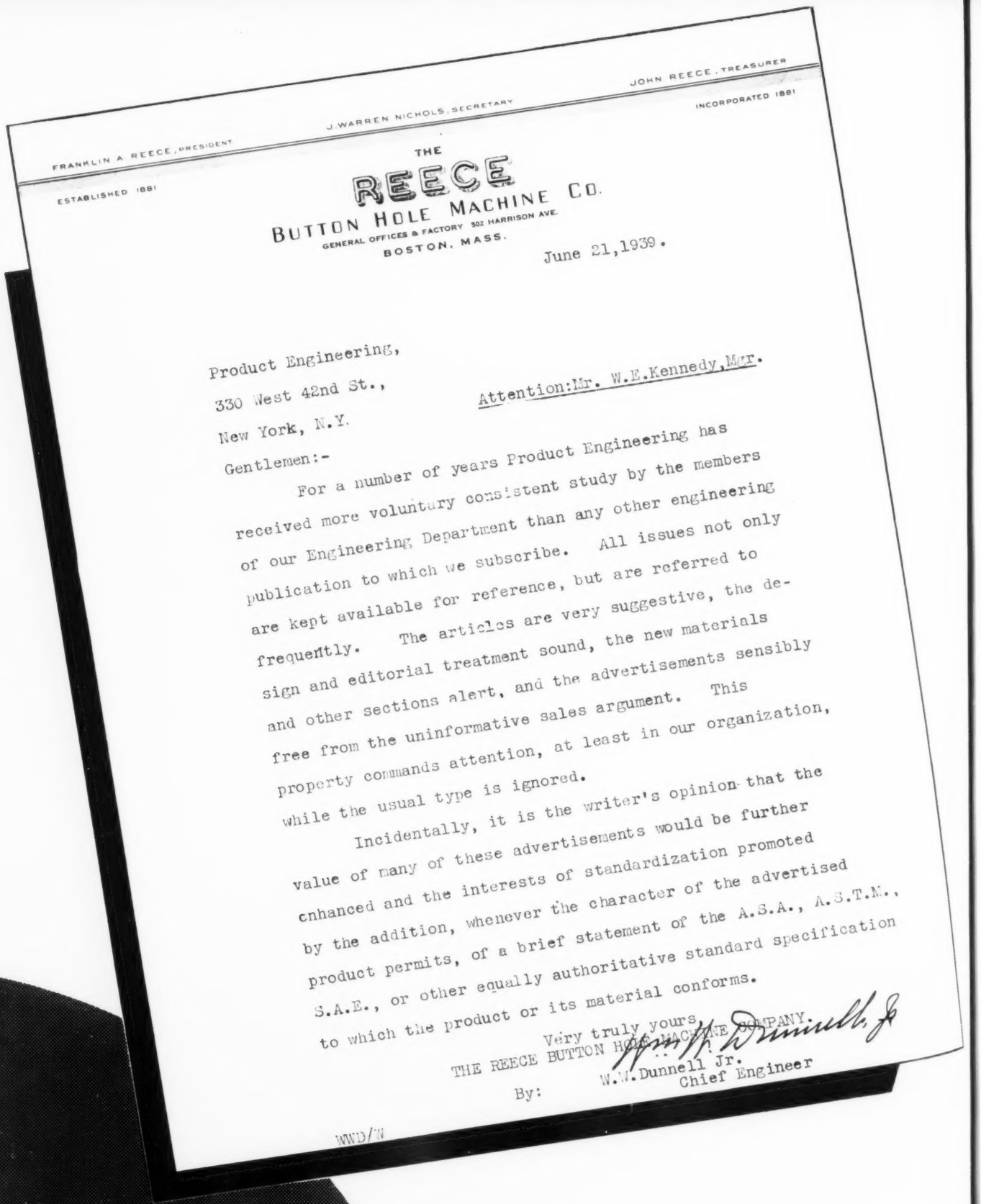
Question and Comment 350

News 353

Meetings 355

New Materials and Parts 356

Manufacturers' Publications 360



FRANKLIN A. REECE, PRESIDENT — J. WARREN NICHOLS, SECRETARY — JOHN REECE, TREASURER

ESTABLISHED 1881 — INCORPORATED 1881

THE REECE BUTTON HOLE MACHINE CO.

GENERAL OFFICES & FACTORY 302 HARRISON AVE.
BOSTON, MASS.

June 21,1939.

Product Engineering,
330 West 42nd St.,
New York, N.Y.

Attention:Mr. W.E.Kennedy,Mgr.

Gentlemen:-

For a number of years Product Engineering has received more voluntary consistent study by the members of our Engineering Department than any other engineering publication to which we subscribe. All issues not only are kept available for reference, but are referred to frequently. The articles are very suggestive, the design and editorial treatment sound, the new materials and other sections alert, and the advertisements sensibly free from the uninformative sales argument. This property commands attention, at least in our organization, while the usual type is ignored.

Incidentally, it is the writer's opinion that the value of many of these advertisements would be further enhanced and the interests of standardization promoted by the addition, whenever the character of the advertised product permits, of a brief statement of the A.S.A., A.S.T.M., S.A.E., or other equally authoritative standard specification to which the product or its material conforms.

Very truly yours,
THE REECE BUTTON HOLE MACHINE COMPANY.
By: W.W.Dunnell Jr.
Chief Engineer

WWD/W

Prominent Product Engineers

Worth Less Than Nothing

THE JOB of every purchasing agent is primarily to buy the cheapest thing that will serve the purpose. Good enough is as good as perfect and the extra cost of unnecessary quality is wasted money. It is the responsibility of the engineering department to specify the materials or parts required so that the purchasing agent might be able to pass judgment on the materials offered by the competing vendors. Unfortunately, it is often impossible, or at least impractical, to write into the specifications all of the properties required of the parts or materials to be purchased.

When only one or a few vendors have the necessary quality of material to offer, the engineering department specifies in the bill of material the name or names of makes or manufacturers. Purchasing agents usually don't like this. It hampers them and they often feel that the restrictions imposed are needless. If under such conditions the prices quoted are "out of line" the purchasing agent will ask the engineering department to approve bids from other manufacturers. This is good business if the engineering department does not become over zealous in its desire to cooperate with the purchasing department.

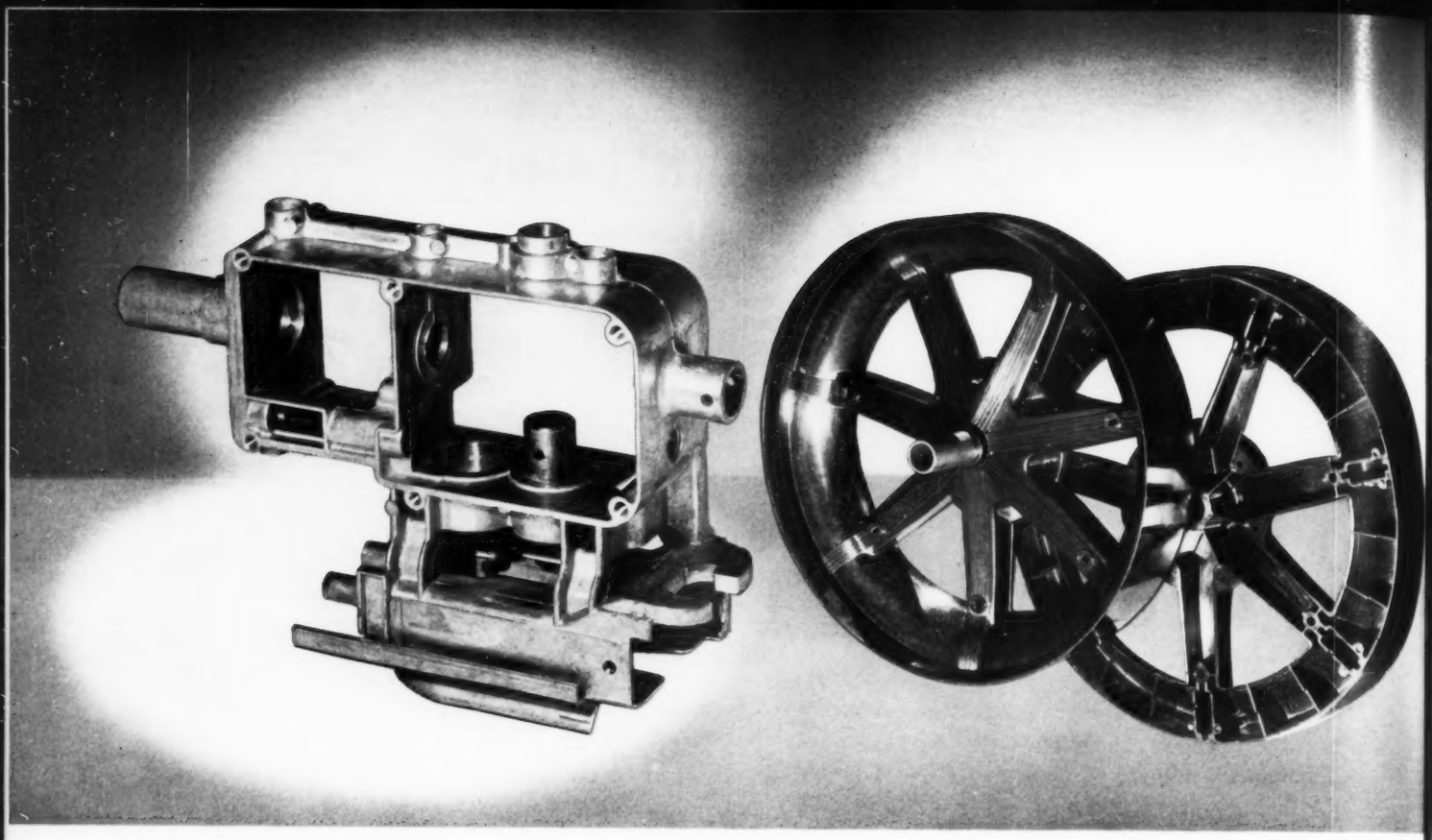
Minor design details play an important part, but because they are minor, they are often neglected. An engineer had specified a certain make of adhesive for fastening felt pads. The purchasing agent found he could get a competing make for less than half the price. The saving of about 50 cents a pound was a strong argument and the engineering department approved the lower price adhesive, a sample of which showed high adhesive strength. The fact that less than a quarter of a cents worth was used on a unit was ignored.

Customers did not complain and it was not until salesmen in the field reported that the pads were falling off, apparently because of the action of oil on the adhesive, that the company found out that the saving of a fraction of a cent on their thousand dollar product was costing them customer good-will.

It would be stupid to ignore the availability of lower cost materials. But it is more stupid to accept them without first subjecting them to rigid tests both in the laboratory and in service. If the possible net savings could not cover the costs of making such tests, no attempt should be made to substitute for the higher cost material of known quality.

This same procedure should be followed in the selection of material used for the first time in which case greatest dependence must be placed on laboratory tests. Reliable manufacturers publish dependable test data for many of the properties of their materials. For tests for special requirements, the engineering department, even in the smaller plants, should have available simple testing equipment. For determinations requiring more expensive and elaborate equipment, the services of commercial testing laboratories should be obtained.

All of the material that goes into a product is put in it to perform a definite service. Therefore, it is service that is being purchased, and if the material purchased is not capable of rendering the service required, it has a negative value. It is worth less than nothing because it does damage instead of rendering service.



DIE-CASTINGS OR PLASTICS

Design Advantages and Relative Costs

HERBERT CHASE

DIFFICULTIES beset any generalization in comparing die-cast with plastic-molded parts, because so many diverse considerations enter. There are numerous types of material for both classes of parts. These types vary greatly in cost and have wide differences in physical properties. Although some generalizations are here made, it should be understood that certain exceptions are to be found. The properties listed in Table I should prove helpful in making a choice between die-castings and plastic-moldings, but more specific comparisons are often necessary.

MATERIALS AVAILABLE. Most plastics of a given type are available in numerous grades and many colors. In die-castings, there are usually two or three alloys of each base metal which are employed for all but exceptional uses. To simplify the discussion, comparisons here made are confined, except where otherwise stated to the most widely used materials. These are zinc alloy for die-castings and phenolic plastic for moldings which, in each category, usually rank lowest in cost per piece, and high in most significant properties.

Cold-molded bituminous plastics cost least per pound. They have some excellent properties and are very rapidly molded. But their strength is low, their finish not as good as other plastics, their gravity high and they have to be baked subsequent to molding.

The ureas, like the phenolics, harden permanently when molded, and are similar in many properties. They cost more and are used chiefly in white or where light tints and translucency are desired. Rubber and the little used soya and shellac plastics are not considered here. All the remaining plastics of significance are classed as thermoplastics which harden on cooling but are softened again if heated to or near the molding temperature.

Thermoplastics have become much more important since the advent of injection molding but their cost per pound ranges from about 30 cents minimum (for black) up to a dollar or more for light translucent or transparent forms. Thermoplastics are used chiefly (*a*) to gain special color effects, transparency or translucency or (*b*) where injection molding results in economy in molding cost, or where both (*a*) and (*b*) apply. Cellulose acetate, except for shellac and perhaps rubber, is the cheapest thermoplastic employed for molding and has gained widest use, especially for injection molding. Cellulose nitrate, which is similar in appearance, and in some other respects sells for about the same or at a slightly higher price and enjoys about an equal or greater sale, is not suited for injection molding and is used chiefly in sheets, rods and tubes, some of which are cut into blanks for compression molding.

Zinc alloys rank first in commercial importance, aluminum alloys second and copper alloys (brass) third. In cost per casting, usually the same order applies, with zinc lowest. Magnesium alloys are relatively new in die-cast form but are growing in importance. Lead and tin alloys, being less strong in physical

Table I—Comparison of Advantages and Limitations of Die-Cast and Molded-Plastic Parts

	Die-Castings	*Molded-Plastics*
MATERIALS AVAILABLE	Two or more alloys of each of following base metals: zinc, aluminum, lead, copper, magnesium, and tin	Various types of acrylic, bituminous, cellulose acetate, ethyl cellulose, phenolic, shellac, soya, styrene, urea and vinyl materials
SPECIFIC GRAVITY	1.83 (magnesium) to 10.65 (lead)	1.05 (acrylic) to 2.09 mineral filled (phenolic)
STRENGTH	Generally superior—including tensile, compressive, bending and impact	Generally not as strong for equal sections but sometimes superior on an equal weight basis
EFFECT OF HEAT	Generally of no significance up to 300 deg. F. for zinc and up to higher temperatures for aluminum and brass. Lower for lead and tin	Distortion from 120 deg. F. upward and softening from 140 deg. F. upward for thermoplastics. Most others distort or discolor from 160 to 240 deg. F. Some usable to about 450 deg. F. maximum
HEAT CONDUCTION	High	Low (an advantage in some applications)
ELECTRICAL PROPERTIES	All conductors	All dielectrics
MALLEABILITY	Good to poor	Usually nil at room temperature
LIGHT TRANSMISSION	All opaque	Cheaper materials opaque, others opaque, translucent or transparent
SMOOTHNESS OF SURFACE	Can equal moldings in some alloys—often not as good, but suitable for applied finish	Usually excellent
COMPLEXITY OF FORM	Often extreme and more complex than feasible with plastics	Often complex but coring more limited than with die-castings
VARIATIONS IN SECTION THICKNESS	Nearly unlimited, ranging from about 0.015 in. to almost any desired max. in important alloys even in same casting	Can vary widely as between different moldings but variation is often limited in a single molding
DIMENSIONAL ACCURACY	Generally better than moldings, plus or minus 0.001 to 0.003 in. per in. are commercial tolerances	Not as good as die-castings; will sometimes warp, plus or minus 0.005 in. in 1 in. are commercial tolerances
APPEARANCE	Most shapes and details on par with molding. Color and gloss (as cast) not as good as moldings	Superior in color, gloss, transparent and translucent effects. On par in shape and details
APPLIED FINISHES	Wide range available, including plating and organic both baked and air dried. No finish needed on large proportion of mechanical parts where appearance is not a factor	Usually none required. Many available if needed
COST OF DIES AND MOLDS	Likely to be lower	Likely to be higher and to involve higher maintenance costs
PRODUCTION RATE	Usually much higher especially as compared with compression moldings	Usually much lower for compression moldings and considerably lower also for injection molding
COST PER LB., (*Materials only*)	8¼ c. for zinc alloy to about 30 c. for magnesium, and about 40 c. for tin	Cold molded, general purpose phenolic, 12 c. min. Other plastics vary from about 16 c. to $1.00 or more per lb.
COST PER PIECE (*No applied finish*)	Often lower, but some exceptions depending in part on cost of materials compared and section thickness used	Sometimes lower, but often higher, but the difference is frequently offset by savings in finishing cost when die-casting compared requires an applied finish
WASTE IN SCRAP	Small and usually negligible	Often considerable
COST OF MACHINING	Likely to be lower but fin removal often costs more	Likely to be greater when required but may be offset by lower cost of fin removal

properties, are confined in use chiefly to special applications in which certain types of corrosion resistance are primary requisites.

SPECIFIC GRAVITY of magnesium alloys is lower than that of the heaviest plastics, and that of aluminum about or on a par therewith, but the bulk (perhaps 90 per cent) of all plastics used are lighter than any die-cast alloys. For this reason, where light weight is essential, plastics deserve consideration.

TENSILE STRENGTH, only the unimportant lead and tin die-casting alloys are below 32,000 lb. per sq.in., whereas 13,000 lb. per sq.in. is about the maximum for a molded plastic, and the majority range around 6,000 lb. per sq.in. As compared to this the zinc alloys range from 43,000 to 48,000 lb. per sq.in., the aluminum alloys from 29,000 to 36,000 lb. per sq.in., the magnesium alloys from 30,000 to 33,000 lb. per sq.in. and from 55,000 to 95,000 lb. per sq.in. for brass alloys.

COMPRESSIVE STRENGTH, 36,000 lb. per sq.in. is a maximum for molded plastics and 18,000 lb. per sq.in. is quite common. This compares with 60,000 to 93,000 lb. per sq.in. for die-cast zinc alloys. Copper-base alloys doubtless run much higher and other alloys lower than the zinc alloys in compressive strength, although specific data are lacking.

IMPACT STRENGTH, strictly comparable data are lacking but 2.4 ft.-lb. Izod and 3.1 ft.-lb. Charpy both on ½ x ½ in. notched bars are the highest authoritative figures the author has been able to find for any except certain little used rubber-base plastics. One ft.-lb. Izod is uncommonly high for most of the plastics that are used in large quantities. Die-castings, on the other hand, show Charpy impact figures for ¼ x ¼ in. unnotched specimens of about 2.5 ft.-lb. average for aluminum, about 18 ft.-lb. for zinc and over 36 ft.-lb. for brass. In other words, plastics generally are much more brittle than die-castings, the zinc and brass alloys especially, which are not only tough but malleable.

HEAT EFFECTS are not often of significance with die-castings but sometimes have to be given consideration. Thus, zinc alloys are not recommended for prolonged use above 250 deg. F. Aluminum alloys withstand prolonged use at temperatures up to 600 deg. F. Some alloys usually classified under "brass," such as aluminum bronze, can be used safely under certain conditions up to 900 deg. F., whereas other brasses oxidize and scale at this temperature. In some alloys used for die casting, elevated temperatures affect physical properties, such as creep and hardness, hence

it is best to investigate each alloy considered before making a selection for an application in which elevated temperatures are encountered. As to plastics, certain phenolic types can withstand, at least temporarily, temperatures up to 400 or 450 deg. F., but charring results if the temperature is much above this and warpage of phenolic-moldings often occurs at or below 240 deg. F. The maximum continuous temperature considered allowable for urea moldings is 160 deg. F. and even this may result in warpage, especially if the heating is localized. For thermoplastics, 140 deg. F. is usually the maximum allowable and the figure may be lower, as softening usually starts at about this temperature and distortion sometimes occurs at 120 deg. F. Being poor conductors of heat, plastics are pleasant to touch and make good handles within allowable temperatures.

ELECTRICAL PROPERTIES favor the die-casting when a conductor is required, and plastics when a dielectric is needed. Under certain conditions, either may be used as an insert around which the other is molded or cast.

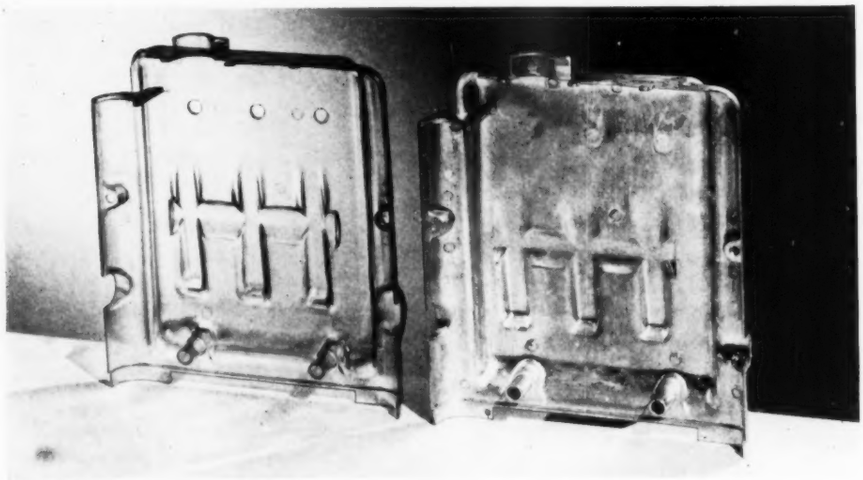
MALLEABILITY, which is absent in molded plastics (unless the temperature be raised to the softening point, in thermoplastics) is found in all die-castings.

CREEP. While no comparative data are available on the various die-cast materials under discussion, it can be said, in general (1) that more consideration must be given to this factor in the case of the thermoplastics than for any of the other materials, (2) that creep is a factor limiting the use of lead and tin die-castings and that sometimes, particularly where elevated temperatures are to be encountered, it must be taken into consideration in designing zinc alloy die-cast parts where the support of high continuous loads is a primary factor.

LIGHT TRANSMISSION is an important consideration in some applications of plastics and, for some materials, is said to be superior to glass. This property permits of certain uses of plastics in lighting and optical effects for which die-castings are not applicable.

SURFACE SMOOTHNESS, especially as it affects finishing cost, is a primary consideration in some parts and of little or no significance in others. Flow marks, draw marks and other surface imperfections sometimes occur on both types of part. Molded plastics often show what is termed "orange peel," a slight irregularity in the surface, and die-castings often have a "splattered" look and slight surface pores, but in both these effects can be avoided by proper die construction and care in molding and casting, respectively.

COMPLEXITY OF FORM not to be duplicated by other rapid production processes is characteristic of many die-cast and molded-plastic products but the complex side coring, often done at several odd



Bottom covers for radio tuning device. Overall dimensions are about $5^1/8$x$6^1/4$x$1^1/4$ in. Average section thickness is about 0.040 in. For part die cast in zinc alloy, the total cost of die and tools for flash removal was $918 (die only cost $730). Cost of castings in lots of 25,000, 11 c. per piece. The die has a single cavity and required 5 weeks to make. Castings are produced at the rate of about 125 per hr. No finish is required. The piece weighs 7.1 oz. To secure some transparent samples in cellulose acetate for demonstration purposes only, the same die used for the die-casting was polished at an added cost of $80 (40 hr. work) and was used in an injection molding machine to turn out between 500 and 1,000 moldings. The latter cost 13 c. each (or were figured to cost this amount in larger lots) with production at the rate of 74 per hr. The molding, which is a duplicate of the die-casting except for the greater shrinkage, weighs 1.44 oz. Purchaser states that the molded part was not considered for production because it is sensitive to changes in temperature and humidity and is too soft. Moreover, a metallic housing was required for shielding against motor noise. The die-casting was selected for production rather than the molding because of the simpler assembly which was made possible by including several bosses and ribs to support parts of the mechanism. Use of parts of transparent cellulose acetate make it possible to see parts within the housing without removing the cover. With polishing (essential for a transparent molded part) the added cost for the die only is $80 or an increase of about 11 per cent over that for the die-casting die only, but had it been desirable to use plastic in production some saving on cleaning tools might have resulted.

Housing, over-all dimensions about $5^1/2$x$5^1/2$ in. Average section thickness $^1/_8$ in. For part die cast in zinc alloy, the total cost of die and tools for flash removal was $960. Cost of casting in lots of 25,000, 14 c. each (without applied finish). Single-cavity die required 3 weeks to complete. Casting production, 175 per hr. Cost of plating in chromium, 30 c. each. Weight of casting, 14 oz. Same piece figured for production in urea plastic: Cost of single-cavity mold $1,025; cost of molding in lots of 25,000, 28 c. each. Five weeks required to make mold. Rate of molding is given as 40 to 50 per hr., which is probably an error, as urea moldings of this size are seldom produced in a cycle of less than 3 min. No applied finish required. Advantages cited for die-casting are: important dimensions held within 0.0005 in., any type of finish can be applied, about 95 per cent less breakage in transit.

angles in die-castings, has yet to be matched in molded-plastics, although some simple and relatively shallow side coring is done. With the advance of injection molding, more complex coring is being done and the molder may yet produce parts as complex as those made by die casting.

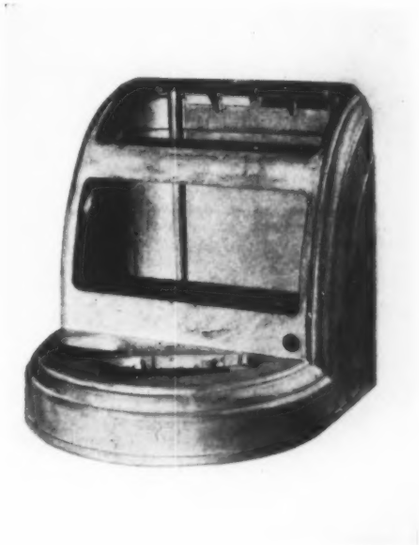
VARIATION IN SECTION THICKNESS. In die-castings very abrupt changes in section are permissible but some slight filleting is necessary for strength, as in other materials. Sudden variations in section are more likely to give trouble in the molded part, especially when the latter is in a thermosetting plastic, as thin sections may be overcured if the thick ones are cured fully; or, if the thin sections be properly cured, thick ones may be left hard on the surface and pithy below the surface. Cracking and or distortion is likely to occur in moldings with thick and thin sections because the heavy sections tend to shrink more than the thinner ones.

Section thickness of parts designed for the same service and thus (ideally, at least) of equal strength, can be less with the die-casting than with the molded-plastic, because the die-casting is much stronger, section for section. This gives more space inside a hollow part having the same outside dimensions. It does not follow that the molding, if made with thicker walls to give equal strength will necessarily be heavier, as the lower specific gravity of the plastic may more than offset the added thickness. Also, a thicker wall may yield added stiffness which may be advantageous. Much depends, however, on which plastic is compared with which die-casting alloy.

DIMENSIONAL ACCURACY tends to favor the die-casting, partly because the molded part undergoes more shrinkage after removal from the mold. It is necessary to cool some moldings over forms or in clamps to avoid warpage and to minimize dimensional changes, a practice not required with die-castings. Commercial tolerances on ordinary phenolic and urea plastic-moldings are plus or minus 0.005 in. on dimensions of ½ to 1 in. measured parallel to the mold-parting and double this at right angles to the parting. With acetates, about 20 per cent greater tolerances are allowed. In die-castings, the tolerances as determined by fixed dimensions of the die, are plus or minus 0.001 in. per in. for zinc, tin and lead alloys, plus or minus 0.002 in. per in. for aluminum alloys and plus or minus 0.003 in. per in. for brass. As with plastics, dimensions measured across the die-parting or as between parts of the die having relative motion require a greater tolerance than those determined by fixed portions of the die, but in all instances (as the figures given show) the die-casting tolerances are closer than those for molded parts. Significant dimensional changes often occur in molded parts (other than normal expansion and contraction with changes in temperature) whereas, with modern die-casting alloys, such changes are nearly always negligible.

FINISHING COST usually tends to favor the molded-plastic since, as a rule, being already in the desired color, with a natural finish which is highly resistant to corrosion and possessed of requisite luster it needs no applied finish. This is important, as finishing costs on a die-casting sometimes equal or exceed the cost of the casting itself. If, as sometimes happens, the part must be given

Cover for thermostat die cast in zinc alloy and also molded in black phenolic plastic. These parts are not identical in design but are about the same size. Overall dimensions are approximately $4\frac{3}{4}$x $1\frac{3}{4}$x$1\frac{1}{8}$ in. Section thickness for die-casting averages approximately 0.045 in. and for the molding approximately 0.075 in. Total cost of die (single cavity) for casting and cleaning tools was $825, which included engraving to provide thermometer scale markings not provided in the mold. Moldings therefore require addition of separate scale plate which is not needed in the die-castings. Total cost of two-cavity mold for plastic was $8[illegible]5. Each required six weeks to make. Total number of parts estimated was 25,000 for each material. In lots of 2,500, the piece price was 8.9 c. for the die-casting and 12.99 c. for the molded part. The die-casting weighs $4\frac{1}{4}$ oz. and the molded cover $1\frac{3}{4}$ oz. Approximate number of parts die cast per hr. was 175; the rate for molding production was not given. Both die cast and molded parts were sprayed with lacquer, the die-casting receiving three coats at a cost of 3.5 c. per piece and the molding two coats at a cost of 2.6 c. per piece. Advantages cited for the die-castings are greater strength and lower cost; for the molded parts, dielectric qualities and lighter weight.



Display stand die cast in zinc alloy. Over-all size about $9\frac{1}{2}$x$9\frac{1}{2}$x11 in. Piece weighs $5\frac{3}{4}$ lb., approximate section thickness is 0.075 in. Total cost of die and fin removing tools, $3,250. Cost in lots of 10,000, $83\frac{3}{4}$ c. per piece. Approximate time required to finish single-cavity die was 5 weeks. Finish, black enamel, cost not given. When figured for production in phenolic plastic, the estimated cost of a single-cavity mold was $4,000 and cost per piece in lots of 10,000 was $95\frac{1}{4}$ c. Reason for using die-casting is that molding production would have been too slow, unless more than one mold had been provided, which would make mold cost prohibitive.

an organic finish, whether it is a die-casting or a molded-plastic, finishing cost is then about on a par.

APPEARANCE, as related to parts coming from die or mold, and without applied finish, tends to favor the molding, especially on the score of color. Smoothness and detail as to shape, in general, are on a par. Besides color, the molded plastic can be produced in mottled effects and different degrees of transparency or translucency sometimes giving it a further advantage in appearance.

CORROSION RESISTANCE and freedom from chemical attack are exceptionally high in plastics as they are generally inert chemically. Practically all are affected little, if any, by mild acids and alkalis, and some resist strong alkalis and acids. Acids and alkalis attack most die-casting alloys.

COST OF DIES AND MOLDS is generally lower for the die-casting than for the plastic-molding and is almost certainly so on a basis of equal rates of production. Where the materials used for the dies machine with equal ease, the cost of sinking identical cavities for die casting and molding, respectively, is equal. But, where large production is involved, the mold or plastic will require more cavities, with correspondingly higher cost, because the molding cycle is much longer than the die casting cycle. For zinc alloys and those of lower melting point, dies do not have to be hardened (although they are sometimes hardened for long-run work), whereas molding dies usually require hardening to resist abrasive action. Hardening increases cost, as warping may result and polishing is then usually necessary.

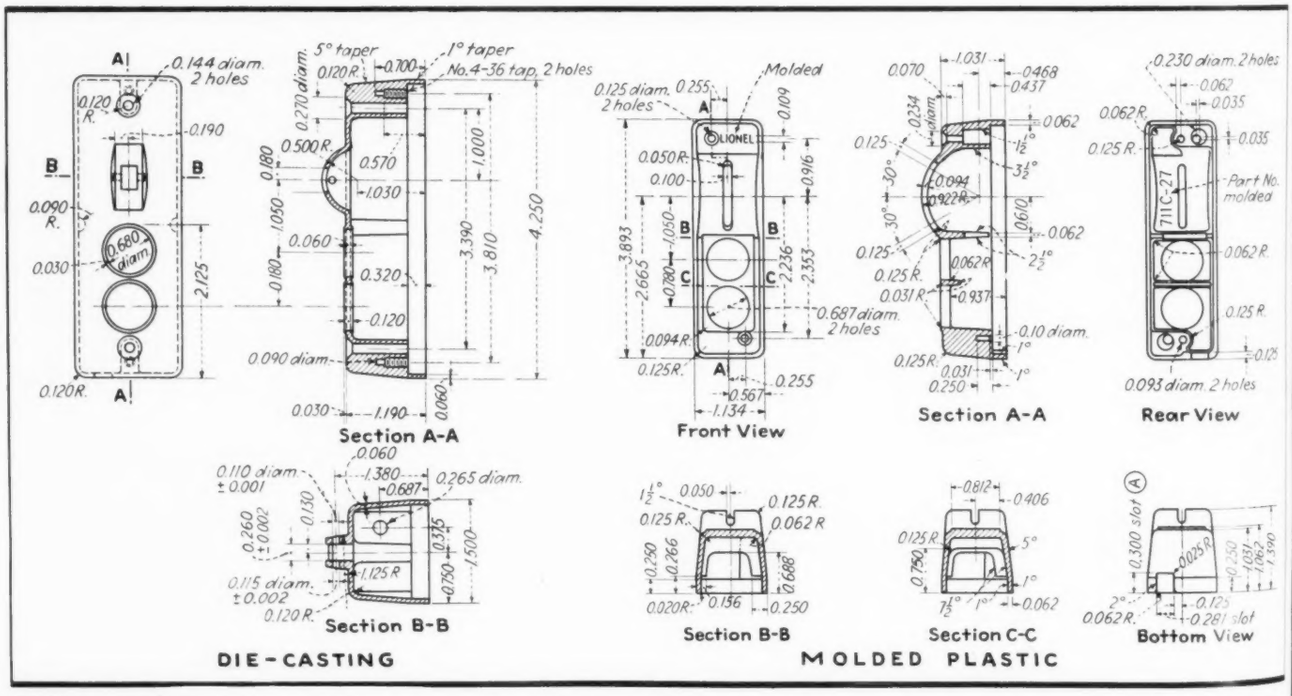
Molding dies, in general, also have to be heavier than those for die casting, as high localized pressures are sometimes encountered especially in compression molding and the pressures applied are higher than in most die casting. It is frequently necessary to spend more time in polishing plastic-molds than is required in casting-dies. Finally, in die casting, it is often feasible to use combination dies to form several differently shaped parts of different sizes simultaneously, and also to employ so-called "unit" dies with individual cavity blocks quickly replaceable. These economy expedients are not feasible in compression molding and are less applicable, if feasible at all, in injection molding.

PRODUCTION RATES are almost always higher in die casting than in molding. Casting cycles range from about 4 sec. for small parts on automatic machines up to about one minute for large parts such as one-piece motorcar radiator grilles. Compression molding cycles have, in certain extreme cases of small parts, using preheated material, been reduced to as little as 18 sec., but a one-minute cycle is exceptionally fast and cycle time ranges upward to 10 min. or more, with the average perhaps 3 min. In injection molding, a higher rate of production is attained, but the cycle is seldom as short as 10 sec. and runs up to at least one minute for the larger molded parts which are at present limited to a maximum of about 2 lb. in weight.

The slower cycle in molding necessitates (for a given rate) more or larger machines, or both, and a higher labor charge per piece. An exception to this rule is found in a few small moldings, such as bottle caps, which can be produced in large molds having as many as 150 to 200 cavities. For such pieces the cycle is short (for compression molding) and the large number of parts per cycle yields a high rate not duplicated in die casting, where the number of cavities per die is more limited. The foregoing comments do not take into consideration the process of cold molding which, though quite rapid, is rather limited in scope and necessitates baking subsequent to molding.

Operations, such as flash removal, which must follow molding and casting, have a bearing on the rate of producing finished pieces. Flash is usually thinner on the molded part and usually may be more easily and rapidly removed than the flash of die-castings. But any work which requires machining, such as the common operation of tapping, is likely to be more difficult and more costly on moldings than on die-castings.

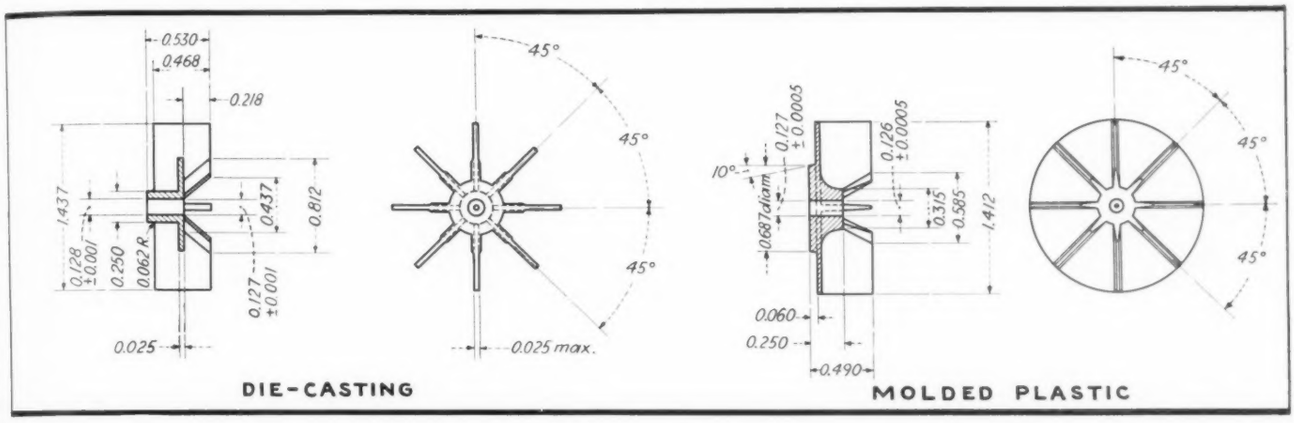
COST OF MATERIALS. The lowest cost



Hollow casings both of which are used over electrical parts. The molded form has the advantage of being a dielectric and of being better in appearance. Advantages for the molded form are: lower cost (see Table II), more enduring finish and decreased shipping weight. Advantages for the die-castings are greater strength and a higher production rate. These die-castings require an applied finish which, however, accounts only in part for their higher cost

molding materials in common use are the general-purpose phenolics which have averaged about 12 c. per lb. for several years. Other plastics range upward to a dollar or more per pound. Zinc alloys are the lowest cost materials for die casting in general use, the price having averaged approximately 8¼ c. per lb. for several years. Other die-casting alloys range upward to about 30 c. per lb. for magnesium to about 40 c. per lb. for tin.

GENERAL CONCLUSIONS are necessarily subject to the many qualifications covered in the foregoing paragraphs. It may be said, however, that both types of product possess remarkable utility. Both types of parts are well suited for many forms of housings and for various decorative applications in which appearance is a primary consideration. Where either can be used, the engineer should weigh the relative advantages and disadvantages, compare costs and then use his best judgment as to which type of part best meets requirements.



Impellers for toy train whistle turns at 7,000 r.p.m., hence any lack of balance (which appears to have resulted from slight porosity in the die-casting) in the part causes vibration. Better balance is reported in the plastic molded impeller and this together with lower weight and lower inertia (permitting of more rapid acceleration and of short blasts from the whistle) are important advantages. Impeller blades in the die-cast form are only 0.025 in. max. in thickness, they are still thinner near the hub and have a web only $\frac{7}{16}$ in. in diameter adjacent to the hub. Some difficulty from bending of blades in handling the die-castings is reported. Advantages named in favor of the die-cast form are a higher production rate and greater ease in making a press fit on the shaft. The molded impeller has blades which taper from 0.050 in. where they join the web or shroud (which has the full 1.412 in. diameter of the blades and is 0.040 in. thick) to a thickness of 0.030 in. This greater thickness and complete support of the blades along one edge naturally yields a stiffer impeller, doubtless contributing to lessened vibration. Despite the greater thickness, the molded impeller weighs about half as much as the die-cast one (see Table II), and costs about one-fifth as much.

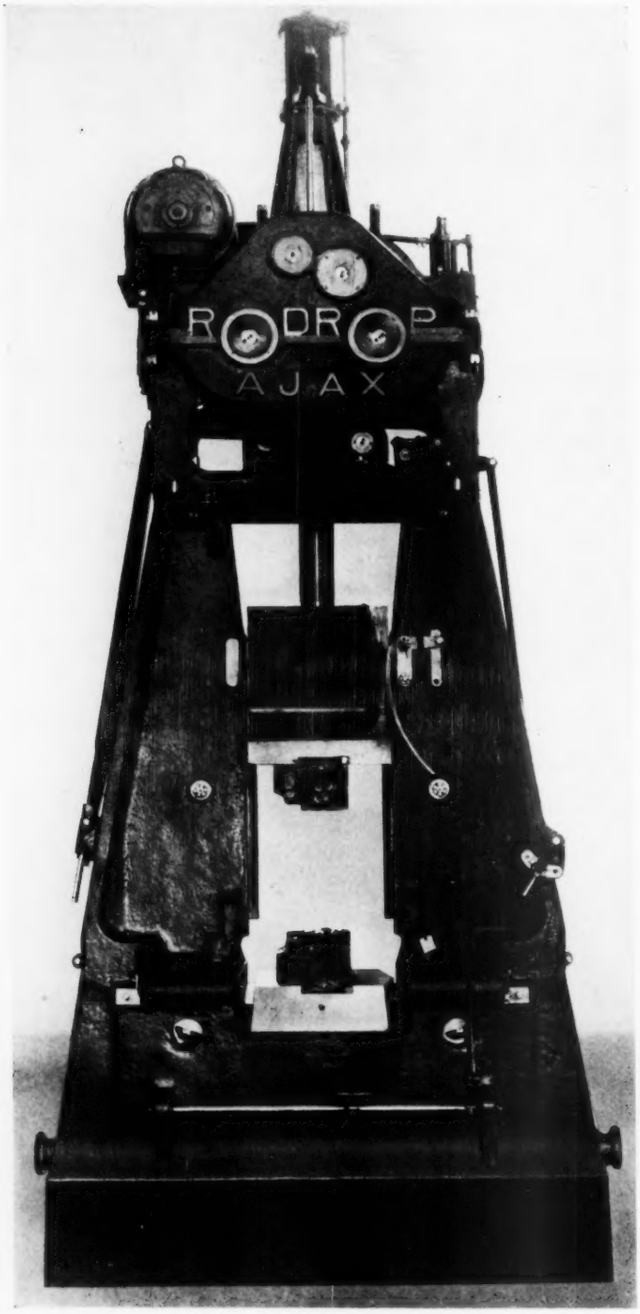
Impellers and casings shown in the preceding drawings are for toy or model railway use and have been in quantity production in both die-cast and plastic-molded form. Table II gives costs and other data concerning these parts. The cost per piece is materially lower for each of the molded parts than for the corresponding die-castings. For both parts the molds and dies have single cavities and mold cost runs from one-third to one-half that for the casting die. Molds required about the same proportionately shorter time to build. Other reasons for this difference in die and mold cost are: Molds are apparently somewhat smaller and have been produced quite recently, by the latest methods, and involved hobbing of cavities on the two larger pieces whereas the older dies had cut cavities in tool steel. As cavities are nearly the same size and shape, it would appear that, on a strictly comparable basis, the cost of sinking them would be substantially the same if the same methods were used in production. In the cost of the casting dies is included that of tools for trimming fins, whereas no corresponding tools for the moldings are required, since fins on moldings are removed by tumbling.

Table II—Cost and Production Data

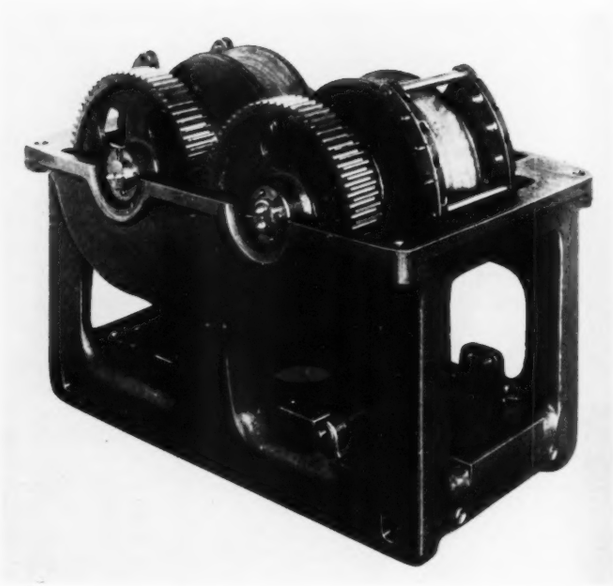
NAME OF PART	WHISTLE IMPELLER		HOLLOW CASING	
Material Used	Zamak No. 6 Zinc Alloy	Bakelite Phenolic Plastic	Zamak No. 6 Zinc Alloy	Bakelite Phenolic Plastic
Total cost of dies or molds and cleaning tools	$450	$150	$550	$235
Number of cavities in die and mold	1	1	1	1
Hours required to make die and mold	250	85	325	130
Total number of pieces in cost estimates	125,000	125,000	30,000	30,000
Approximate number of pieces cast and molded per hr	500	47	250	27
Piece price (without applied finish), cents	1.100	0.211	1.773	1.355
Type of finish applied	none	none	Black synthetic	none
Cost of applied finish per piece, cents	none	none	0.577	none
Total cost per finished piece, cents (Not including die or mold amortization)	1.10	0.211	5.350	1.355
Weight per piece, ounces	0.28	0.136	1.00	1.03

Modern Designs

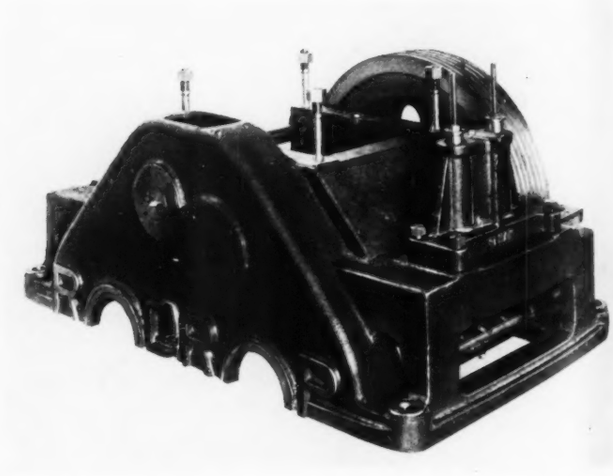
Steel Lift Rod Replaces Boards



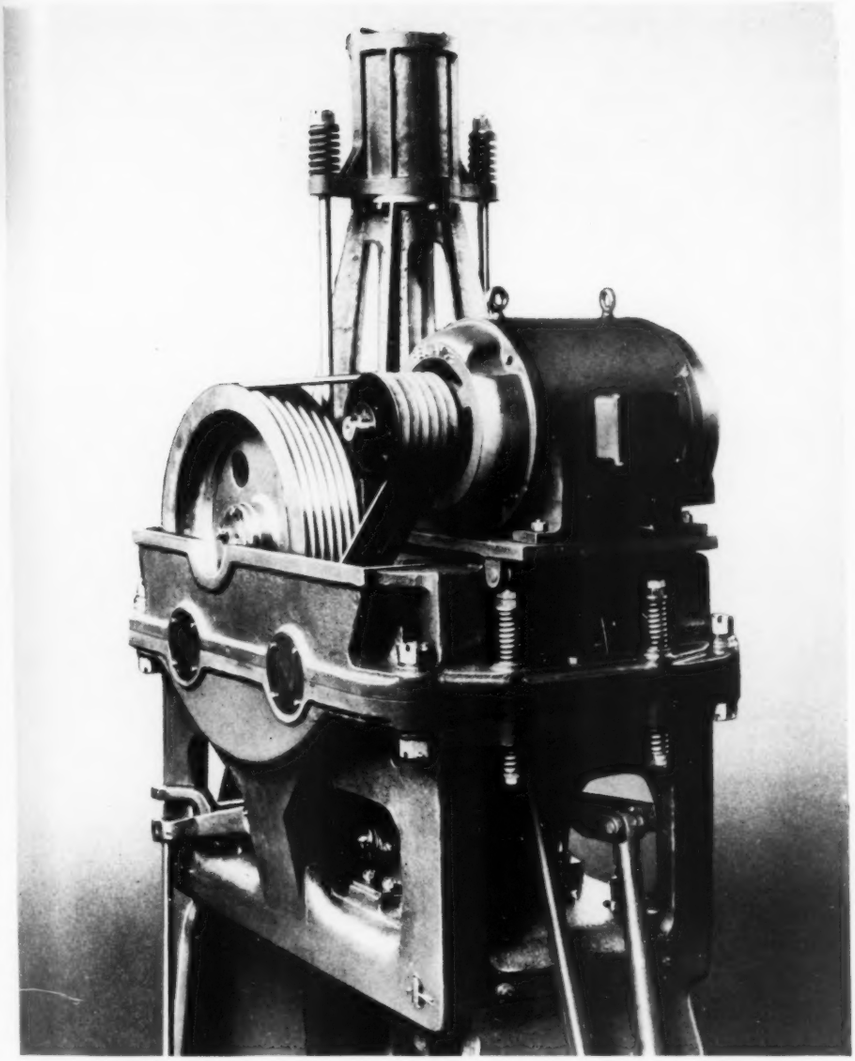
Variable-stroke drop forging hammer developed by the Ajax Manufacturing Co. has the rigid steel lift rod taper-fitted in the ram. Transversely-mounted rolls have V-grooved rims of laminated friction material contacting rod on four sides. Transverse mounting permits increased roll diameter without overhanging the frame, and gives a larger arc of contact thus requiring lower unit pressures, and thereby reducing wear.

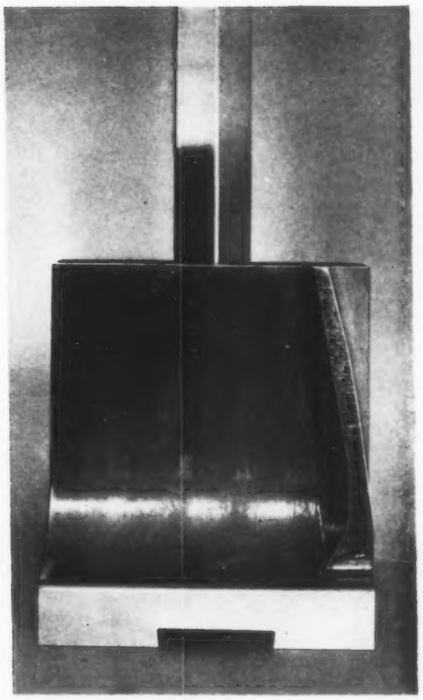


Rolls are mounted on eccentrics and are brought in and out of contact with rod through movement of the eccentric by means of a small air cylinder. Differential valve on the air line to this cylinder, governed by treadle, controls height to which ram is raised before release, making possible blows of varied force. Accelerator cylinder connected to shop air line acts on ram at full stroke, giving quick acceleration or recoil.



Head frame is an open-hearth steel casting with the parting line at the roll eccentric bearings, making rolls and eccentrics easily accessible, should disassembly be required. Head-frame base is a rigidly braced, box-frame steel casting. Head-frame cap carries hinged motor bracket, eccentric closing cylinder and return springs, V-grooved flywheel. Main and intermediate pinions are completely inclosed in an integral housing.



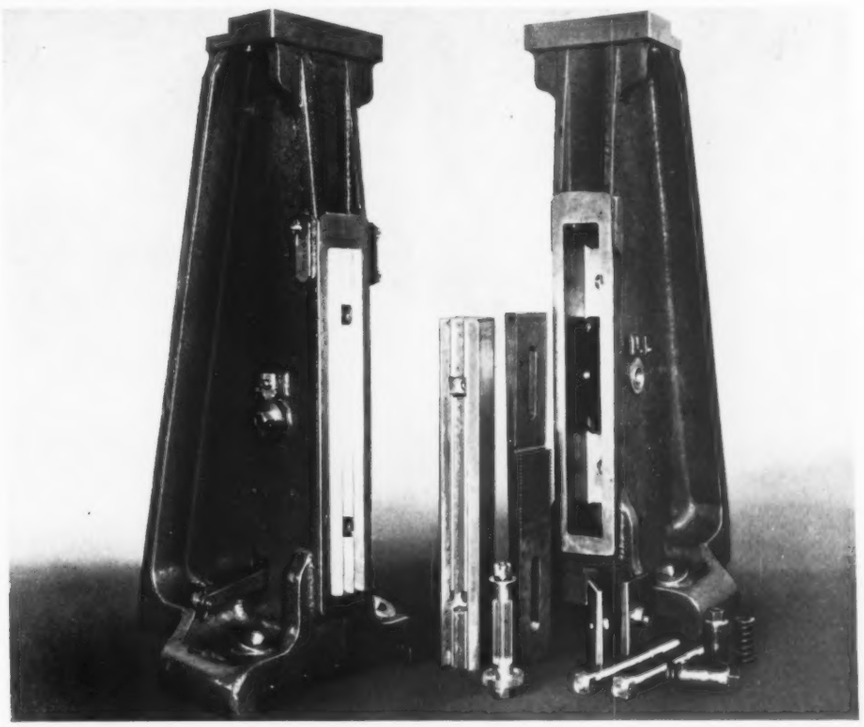


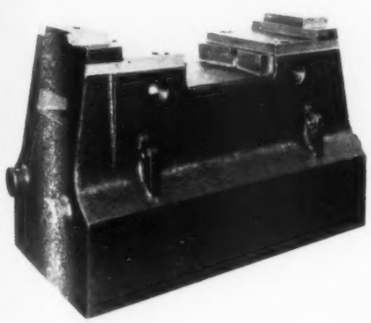
Ram is of forged steel, heat-treated after rough machining. Die seat is grooved to customer's specifications. Tapered rod seat is located well below center of gravity. Steel in lift rod is of piston-rod analysis, ground to an accurate square.

Cast steel columns are rigidly fixed to the steel base. Insert guides of special-analysis, heat-treated forged steel are adjusted by positive-locking, calibrated wedges to obtain matching of the dies.

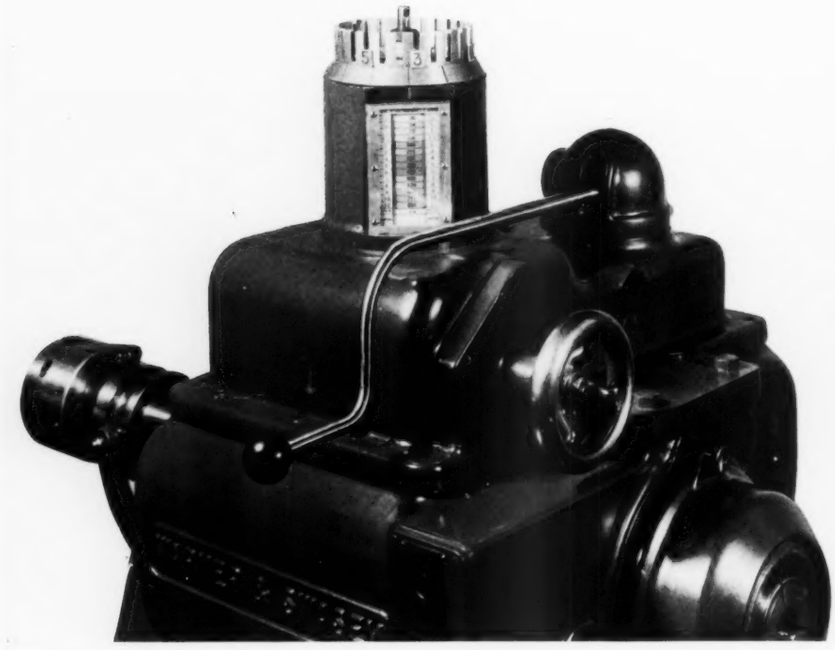
Lifting mechanism is driven by an individual Reliance motor through multiple V-belts and an inclosed flywheel. Motor is mounted on spring cushioned platform. Only one horsepower per hundred lb. of ram weight is required, because of high lifting efficiency and low roll-slippage losses.

Base of the hammer is cast from open hearth steel, and weighs twenty times ram weight. Double-angle seat pockets the sowblock against front to back movement, without use of dowels.

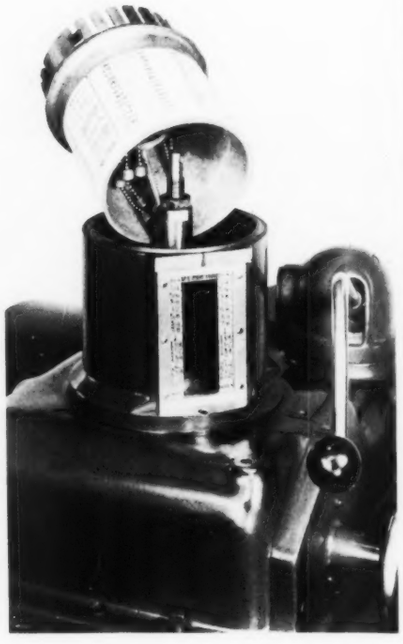




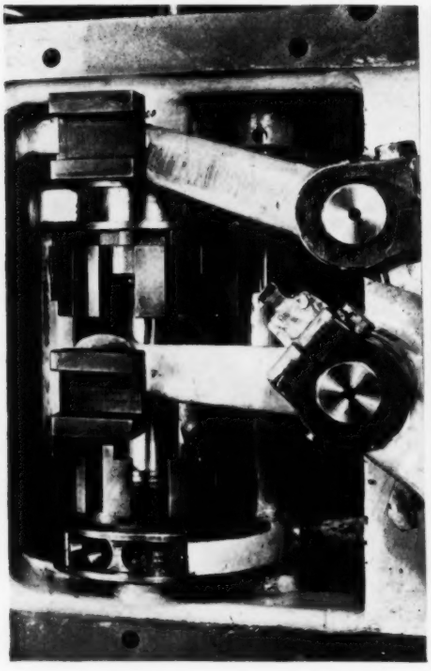
Modern Designs—Pre-Selects Spindle Speed on Turret Lathes

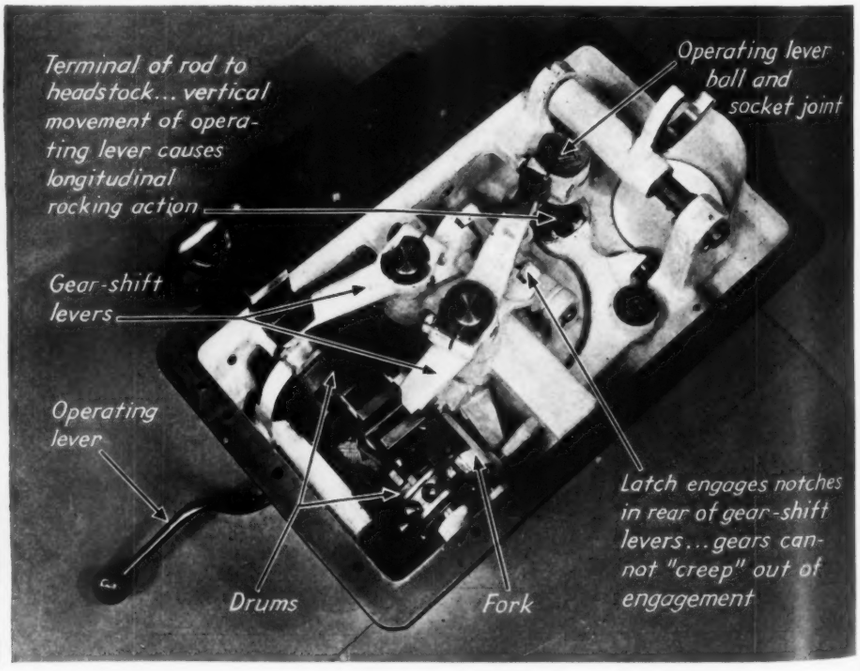


Pre-selector developed by Warner & Swasey engineers for selecting gear ratios for spindle drive on turret lathes has been designed to fit in place of the conventional head cover on the regular headstock. Same gear ratios are used. Cutting speed is indicated in surface ft. per min., not in r.p.m. of spindle. By turning a handwheel, gears can be preset to cutting speed desired for the next cut while machine is running. To change spindle speed, shifting only one lever throws out drive clutch and shifts gears; the drive spindle then runs at the r.p.m. that gives the desired ft. per min. cutting speed. No calculations are required.



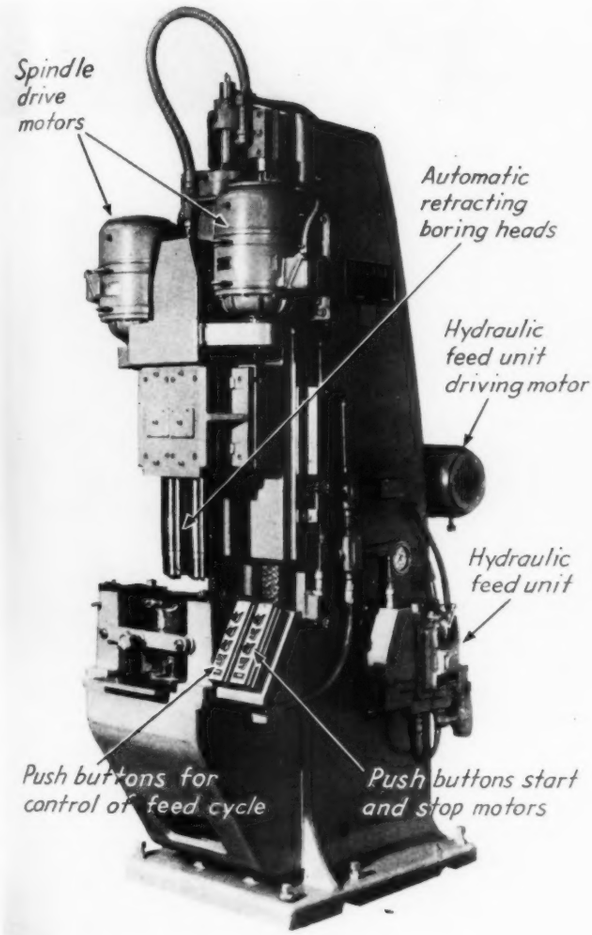
Scales on monitor top indicate cutting speeds in ft. per min. for 28 work diameters. Metal numerals on weighted bead chains are set to indicate sequence of cutting operations. Operator rotates handwheel until number indicating desired speed appears opposite number indicating work diameter.

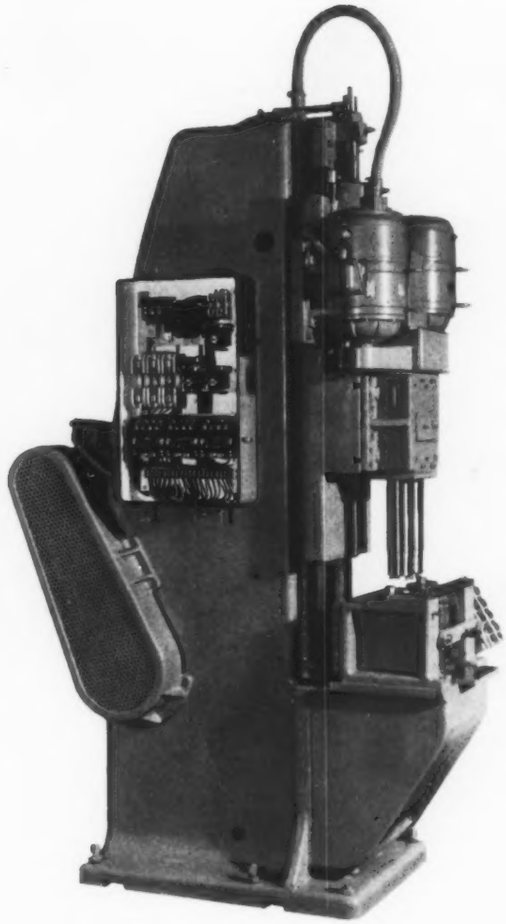



Terminal of rod to headstock... vertical movement of operating lever causes longitudinal rocking action
Operating lever ball and socket joint
Gear-shift levers
Operating lever
Drums
Fork
Latch engages notches in rear of gear-shift levers... gears cannot "creep" out of engagement

Speed selector mechanism has two drums which are rotated by the handwheel on the front end of the head. These drums have fingers of various lengths which position drums in thirteen possible combinations of relative axial position which determine gear combinations. Handwheel which rotates drums is connected to monitor unit by means of a spur gear train and spiral gears. The gear shift levers are connected with additional levers that have projections which reach between the drums. These are so arranged that when the drums are brought together to positions as determined by length of the drum fingers the accompanying lever movement shifts gears to proper positions.

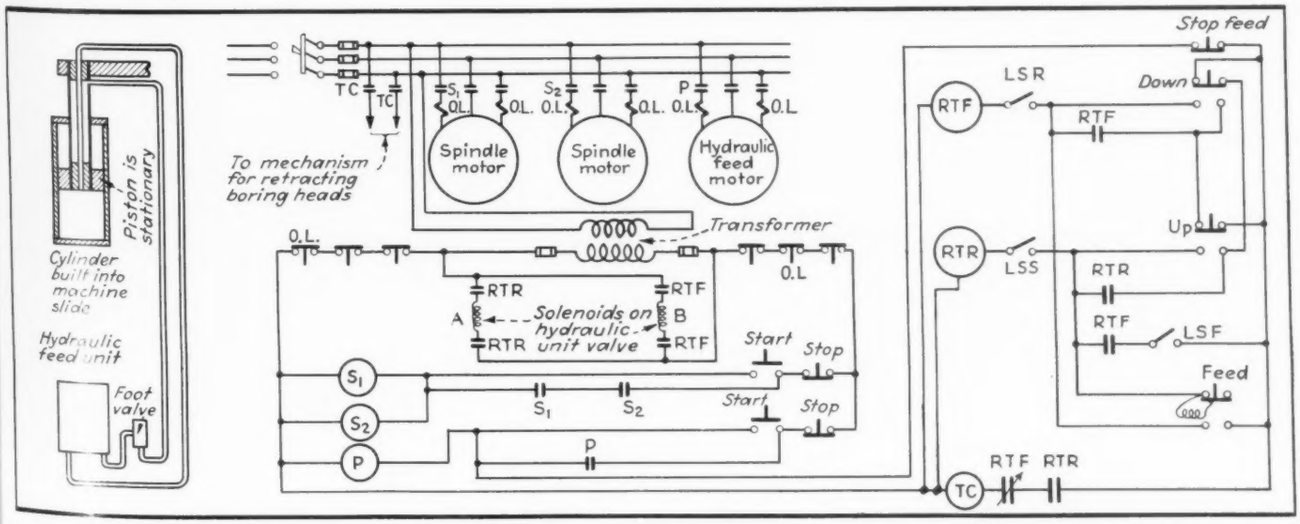
Electrically-Controlled, Hydraulic-Feed Boring Machine


Spindle drive motors
Automatic retracting boring heads
Hydraulic feed unit driving motor
Hydraulic feed unit
Push buttons for control of feed cycle
Push buttons start and stop motors



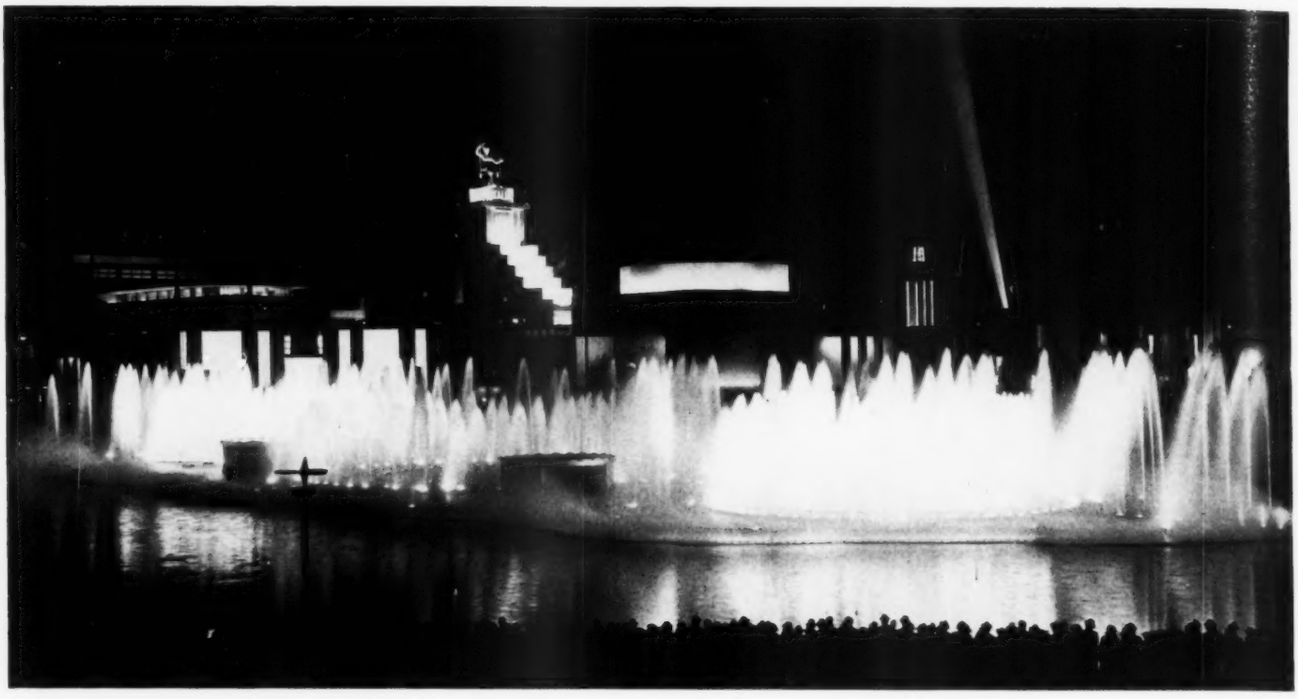
Push button control of motors and feed cycle is built into this vertical, hydraulic-feed, two spindle machine designed by Moline Tool Company for finish boring engine cylinders. Boring spindles are of the extended-sleeve type, driven through V-belts by separate motors.

Automatic retracting heads are used on spindles to permit boring of cylinders in which an interrupted cut occurs. Retraction of cutting tools is controlled electrically. Boring heads retract only when solenoid-operated valve on hydraulic unit causes rapid reverse travel of the tools away from the work.

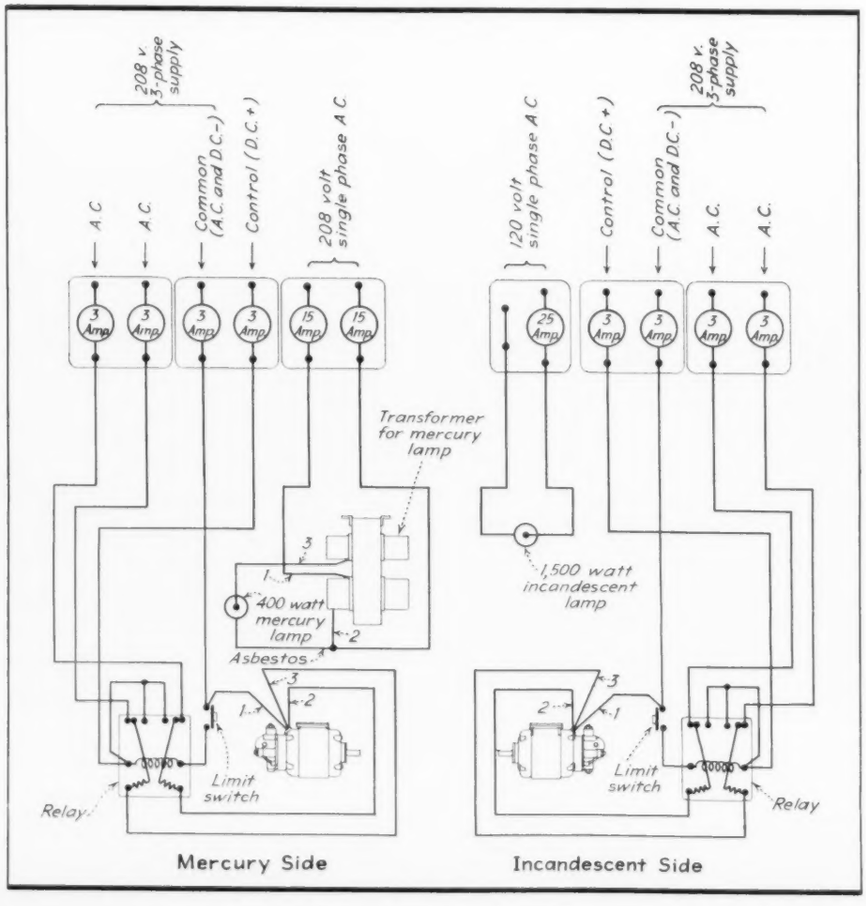


Single push button station controls all functions. One group starts and stops spindle motors and the hydraulic-feed unit driving motor. The other group controls feed cycle: one button initiates an automatic cycle, the other three (1) rapid-reverse traverse from any point above position where feed is automatically thrown in, (2) travel at feed rate from any point above position where limit switches automatically throw in feed, and (3) stop travel at any point.

Modern Designs —585 Twin Light Projectors in Fair's Color Symphony

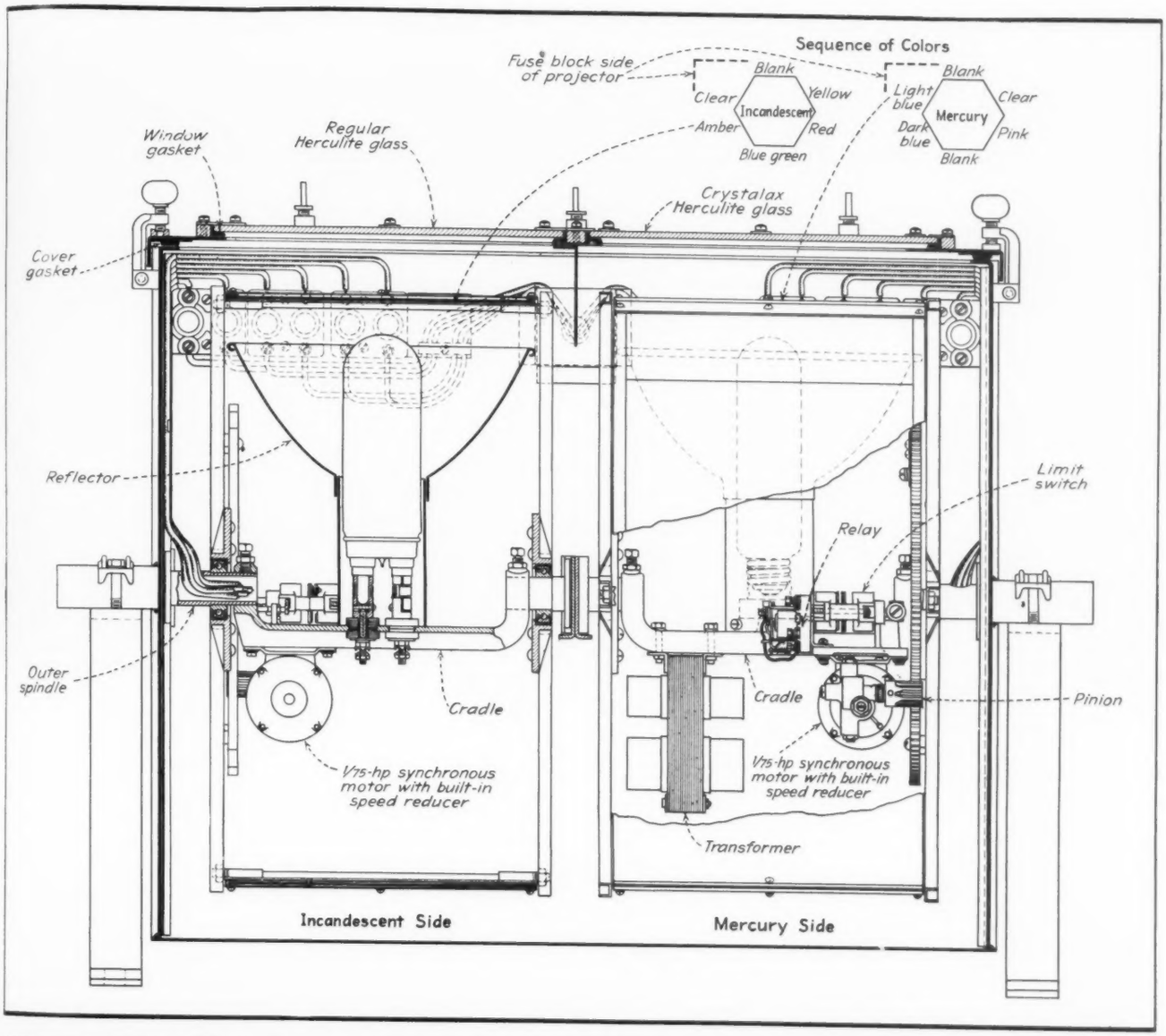


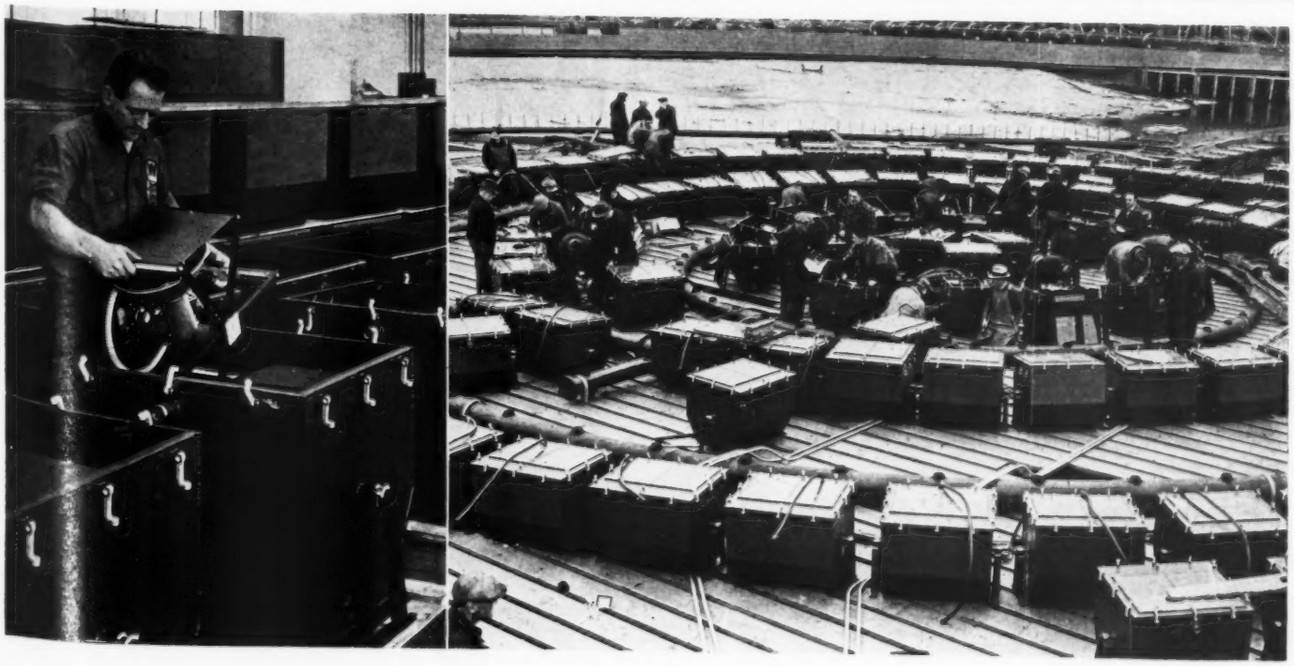
Pulsing jets of water, illuminated by changing colored lights synchronized with music, form a color symphony in the Lagoon of Nations at the New York World's Fair. Illumination is provided by 585 specially developed light projectors submerged in the lagoon. Designed by Westinghouse, the projectors house a 1,500 watt incandescent lamp and a 400 watt high intensity mercury lamp, and two rotating color wheels; the Mazda lamps provide red and amber rays, the mercury lamps a rich blue light. The mercury lamp has an output of 18,000 lumens, the Mazda 37,950 lumens.



Each color drum is driven by a 1/75 hp. synchronous motor with a built-in speed reducer; combination of speed reducer and large ring gear produces a drum speed of one r.p.m. Color drums, motors and auxiliary apparatus are mounted in a watertight sheet steel housing. Panels in the housing cover are of special heat-treated glass. With 1,170 color drums in operation simultaneously, exact control of motors is necessary. To prevent coasting when a.c. supply is disconnected, the motors are stopped abruptly by 60 volts d.c. across their terminals. To insure identical position of all drums at the beginning of each show, each color-wheel motor has a re-synchronizing limit switch and relay.

Relay operating coil is designed for operation on d.c. Each color drum is equipped with a cam that operates the limit switch. To synchronize, the d.c. circuit is energized, the cam closes the limit switch and supplies d.c. to the relay operating coil. As the coil is energized, the three-phase a.c. supply is disconnected and d.c. is applied to the motor windings for braking. After synchronization, the color drums are started by removing the d.c. used for braking.


Sequence of Colors
Fuse block side of projector
Blank
Clear
Yellow
Incandescent
Amber
Red
Blue green
Blank
Light blue
Clear
Mercury
Dark blue
Pink
Blank
Window gasket
Regular Herculite glass
Crystalax Herculite glass
Cover gasket
Reflector
Limit switch
Relay
Outer spindle
Cradle
Cradle
Pinion
1/75-hp synchronous motor with built-in speed reducer
1/75-hp synchronous motor with built-in speed reducer
Transformer
Incandescent Side
Mercury Side



KOROSEAL

Properties and Characteristics

H. F. FRITZ, *THE B. F. GOODRICH COMPANY*

BASICALLY a thermoplastic elastic material, Koroseal can be processed on standard rubber machinery; it can be molded, extruded or calendered without vulcanization. The raw material is an acetylene derivative, a polymer of one of the vinyl halides combined with different percentages of various plasticizers, pigments or solvents. Plasticizers are added to impart varying degrees of resilience, ranging from liquid to bone-like hardness; pigments modify physical properties to a slight extent but are principally added for color; solvents are volatile materials which combined with basic Koroseal produce the jelly-like and liquid forms known as Korogel and Korolac, respectively. Since properties of the material vary with the amount and types of plasticizer and pigments used, no absolute values for physical properties can be given.

The tensile strength of the material decreases in proportion to the amount of plasticizer used. The harder compounds have tensile strength in excess of 7,500 lb. per sq. in. The lower limit of tensile strength is 1,000 lb. per sq. in. However the tensile strength of Koroseal compounds is less than that of rubber compounds of equivalent hardness. As with rubber this property can be modified by suitable processing.

Elongation may be varied from 2 to 500 percent depending on the amount of plasticizer. Durometer hardness from 15–100 points are available, but since the material is thermoplastic, hardness varies with temperature. Like rubber, Koroseal is practically incompressible, volume remaining constant regardless of loading. Compression set at elevated temperature is higher than rubber.

This material can be made nearly glass clear when desired and lends itself to pigmenting and dyeing to produce brilliant and delicate colors, difficult to obtain with rubber. Special compounds under precise production control can be made odorless and tasteless.

Koroseal is being used for oil and bearing seals and gaskets because of its resistance to swelling and disintegration in the presence of mineral and vegetable oils and other rubber solvents. Maintaining original physical properties, Koroseal compounds tend to shrink slightly under such conditions, shrinkage increasing as the temperature is raised. This shrinking is caused by the slight tendency of the plasticizer to dissolve, also causing a slight stiffening of the compound.

Some of the other industrial uses of Koroseal at present are: flame-resistant electrical cable sheathing, textile roll covers for drafting and spinning cotton, insulation for plating racks in chrome plating operations, steel tank lining for nitric and other corrosive acids, beer or beverage tubing, coated silk, cotton and wool for waterproof and washable fabrics, and coated paper for job printing draw sheets.

Other new uses include fabrics for airplane motor and wing covers, fabrics for photographic dark rooms, waterproof aviation suits, colored fabrics for wind cones, and gaskets, tubing and molded parts for instruments, oils and greases. In the field of chemistry, the material is used in paints and varnishes for corrosion and lining containers, coated paper for bags for hydroscopic and corrosive materials, pipe valves and fittings for corrosives, diaphragms for pumps and regulators, cloth and asbestos inserted packing for corrosives and door seals.

The compound is not recommended for use where service conditions require immersion in organic compounds containing chlorine or nitro groups, gasoline or other solvents, or where service conditions require flexing in hot oil. Generally application technique is similar to rubber technique, as the compound can be utilized in every manner that rubber is used and at higher temperatures.

PROPERTIES OF KOROSEAL

COEFFICIENT OF FRICTION. Tests of friction between surfaces of Koroseal and steel, both dry and lubricated with oil (viscosity 100 Saybolt sec. at 100 deg. F.) show the following approximate coefficients:

	Bone Hard Compounds	*Med. Soft Compounds*	*Soft Compounds*
Dry.....	0.13–0.26	0.20–0.70	1.20–1.80
Lubricated	0.13–0.16	0.16–0.30	0.05–0.10

WORKABILITY. Hard compounds can be machined, drilled, sawed or cut.

IMPACT STRENGTH. Softer compounds are not shattered on impact. Impact strength of harder compounds at room temperature approximates 100 in. lb. per sq. in. of cross sectional area. By way of comparison, the hard rubber compound such as is used next to the metal rim of solid tires averages 35 in. lb. per sq. in. under the same test.

ABRASION RESISTANCE. Equal to or superior to rubber under conditions where the abrasion does not generate heat. When the abrasion is sufficiently rapid or severe to cause frictional heat, however, Koroseal will soften and wear away.

CONTAMINATION. Free from contaminating effect in the processing of food products or other materials in which a high degree of purity is essential.

HEAT RESISTANCE. Koroseal is a thermoplastic. It is unlike rubber in that no vulcanization or chemical change takes place in the presence of heat up to 400 deg. F. It begins to soften slightly at 100 deg. F. and becomes quite soft at about 250 deg. F. The jelly flows freely at 310–320 deg. F. The useful temperature range of Koroseal compounds is from 15 deg. below zero F. upward and generally speaking it should not be recommended for use in temperatures over 150 deg. F.

FLAME RESISTANCE. Like most materials containing a high percentage of halogen, Koroseal will burn only while being held in direct contact with flame.

DIELECTRIC STRENTH. The dielectric strength of Koroseal compounds ranges from 250 volts to 850 volts per 1/1000 in. of thickness at room temperature. Increasing the amount of plasticizer decreases the dielectric strength. Tests indicate usefulness as a direct insulator in low tension service not in excess of 600 volts. In high tension work, Koroseal is valuable as a protective coating in combination with other insulating material.

RESISTANCE TO SUNLIGHT. One shortcoming of rubber which has never been entirely overcome is the tendency to oxidize in the presence of direct sunlight. Koroseal compounds are extremely resistant to light in both natural and accelerated tests. Exposure to ultra-violet light from a mercury vapor lamp for 144 hours showed no effects.

FLEXING. In comparative tests of compounds of rubber and Koroseal designed for the same service, the rubber unit failed after 300,000 flexures whereas the Koroseal compound, taken out of test, was still serviceable, after 3,000,000 flexures, indicating a resistance at least 10 times that of rubber. This property adapts Koroseal to a variety of mechanical applications where durability under long continued flexing is an important requirement.

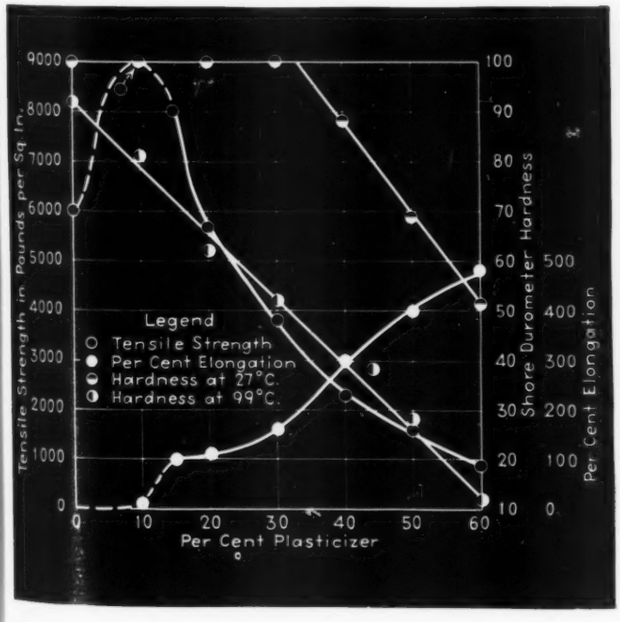
RESISTANCE TO OXIDATION. Unlike rubber, Koroseal shows high resistance to oxidation, the effects being practically negligible. After a period of 96 hours in the Bierer Bomb accelerated aging test, Koroseal compounds were unaffected.

WATER RESISTANCE. Low water absorption is a characteristic of Koroseal, in which respect it is superior to rubber. The increase in weight of certain Koroseal compounds is almost negligible.

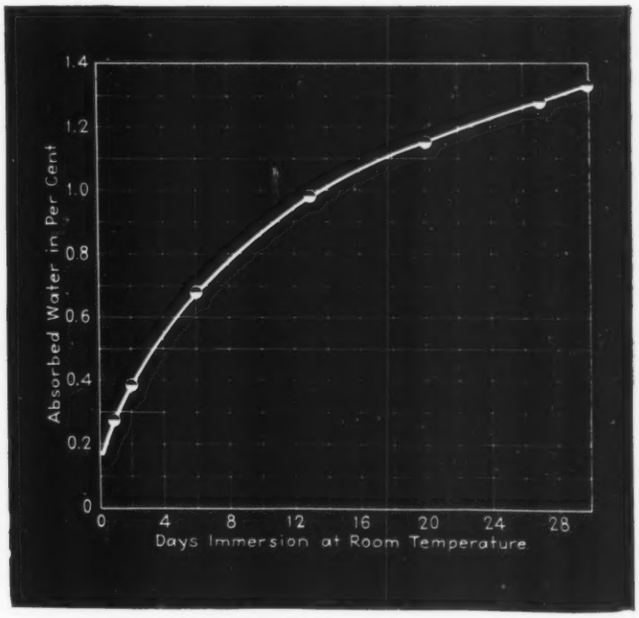
RESISTANCE TO OILS AND SOLVENTS. Koroseal exhibits one of its most remarkable properties in its resistance to swelling and disintegration in the presence of vegetable and mineral oils and other materials classed as rubber solvents. Koroseal compounds tend to shrink slightly under such conditions.

RESISTANCE TO CORROSIVES. Resistant to sulfuric acid in all concentrations at room temperature, nitric acid in all concentrations, hydrochloric acid in all concentrations, alkalis in all concentrations, chrome-plating solutions, thirty per cent hydrogen peroxide concentrate, ten per cent sodium hypochlorite, saturated aqueous sulfurous acid; and all of the well-known commercial heavy chemicals.

(Continued on next page)



Physical properties—tensile strength, elongation and hardness as affected by amount of plasticizer used



Water absorption of typical pigmented Koroseal compound immersed in water for 30 days at room temperature

KOROSEAL: PROPERTIES AND CHARACTERISTICS

(Continued from preceding pages)

Physical Measurements Made at 30 deg. C.

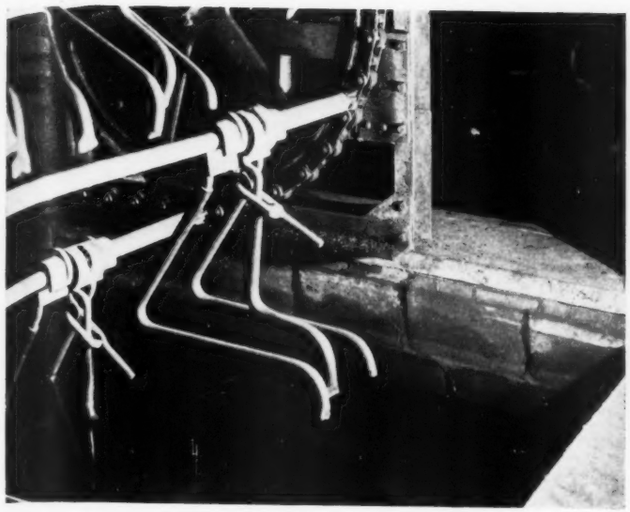
Compound	*A*	*B*	*C*
No Aging			
Hardness — Shore type A Durometer	80	80	82
Ultimate tensile strength (lb. per sq. in.)	2350	2420	2400
Ultimate elongation (per cent)	250	300	225
Aged 2 weeks in Bierer Bomb (300 lb. per sq. in. oxygen at 70 deg. C.)			
Hardness	86	89	80
Ultimate tensile strength	2440	2470	2330
Ultimate elongation	220	280	200
Aged 2 months in Geer oven (circulating air at 70 deg. C.)			
Hardness	83	93	81
Ultimate tensile strength	2500	2520	2210
Ultimate elongation	265	140	215

Electrical Properties

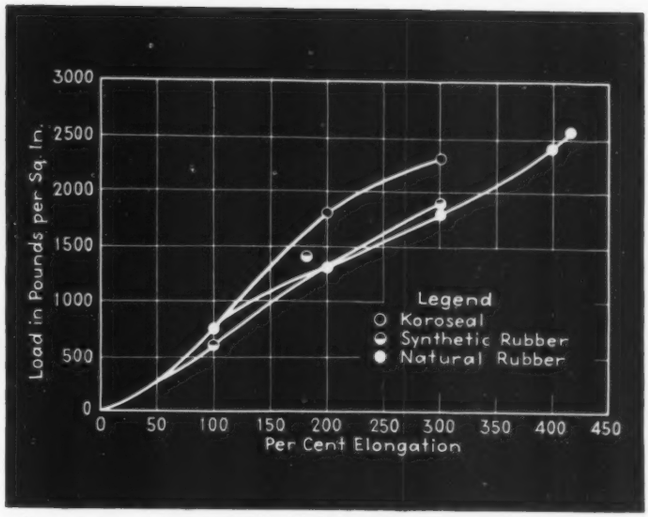
Compound		*A*	*B*	*C*
Resistivity —				
(Ohms per cm.^{3})	at 25 deg. C	....	4×10^{14}	1.8×10^{12}
	45 deg. C	....	5.4×10^{12}	4.7×10^{10}
	70 deg. C	65×10^{5}	7.8×10^{10}	2.5×10^{9}
60-cycle Measurements				
Power factor	at 25 deg. C	....	11.7	14.8
	45 deg. C	....	10.5	16.1
	70 deg. C	4.8	8.8	79.4
Dielectric constant	at 25 deg. C	....	4.1	6.8
	45 deg. C	....	6.8	9.8
	70 deg. C	13.8	8.0	10.7
1,000-cycle Measurements				
Power factor	at 25 deg. C	....	7.9	15.5
	45 deg. C	....	15.6	13.0
	70 deg. C	4.1	5.2	14.1
Dielectric constant	at 25 deg. C	....	3.4	5.1
	45 deg. C	....	5.3	8.3
	70 deg. C	13.0	7.6	10.0

Physical and electrical characteristics of three typical Koroseal compounds

Insulation applications of Koroseal. (1) Control cable; Koroseal insulation; Koroseal sheath with flame-proof braid protection; provides durable insulation and mechanical protection for high temperature application. (2) Generator lead; varnished cambric insulation; lead sheath with Koroseal cover for protection against corrosion and electrolysis. (3) High-voltage power cable; oil-impregnated paper with shielding tape; Koroseal sheath, eliminates trouble from corrosion, electrolysis and vibration. (4) Power cable; improved high-voltage composition; Koroseal jacket for moisture, chemical and oil resistance, also prevents sun checking. (5) Control cable; felted asbestos; Koroseal jacket, moisture resistant and non-combustible. (6) Switchboard or building wire; Koroseal insulates and gives mechanical protection in a single covering, eliminates bulky braids and provides moisture and flame resistance in addition. (7) Control cable; Koroseal in colors; flame-proof braid; identifies conductors. (8) Super-flexible battery lead; Koroseal insulation and mechanical protection in single covering resists abrasion and attack by acid for long periods. (9) Oil well pump lead; Koroseal; Koroseal jacket; steel-taped armor insulates and protects against severe service in oil wells. (10) Rayon spinning motor lead; Koroseal; Koroseal jacket, resistant to lubricating oil and sulphuric acid. Photographs (1) through (8) courtesy the Okonite Company; (9) and (10) courtesy General Electric Company.



Koroseal tubing covers hooks in a Koroseal-lined stainless steel pickling tank application

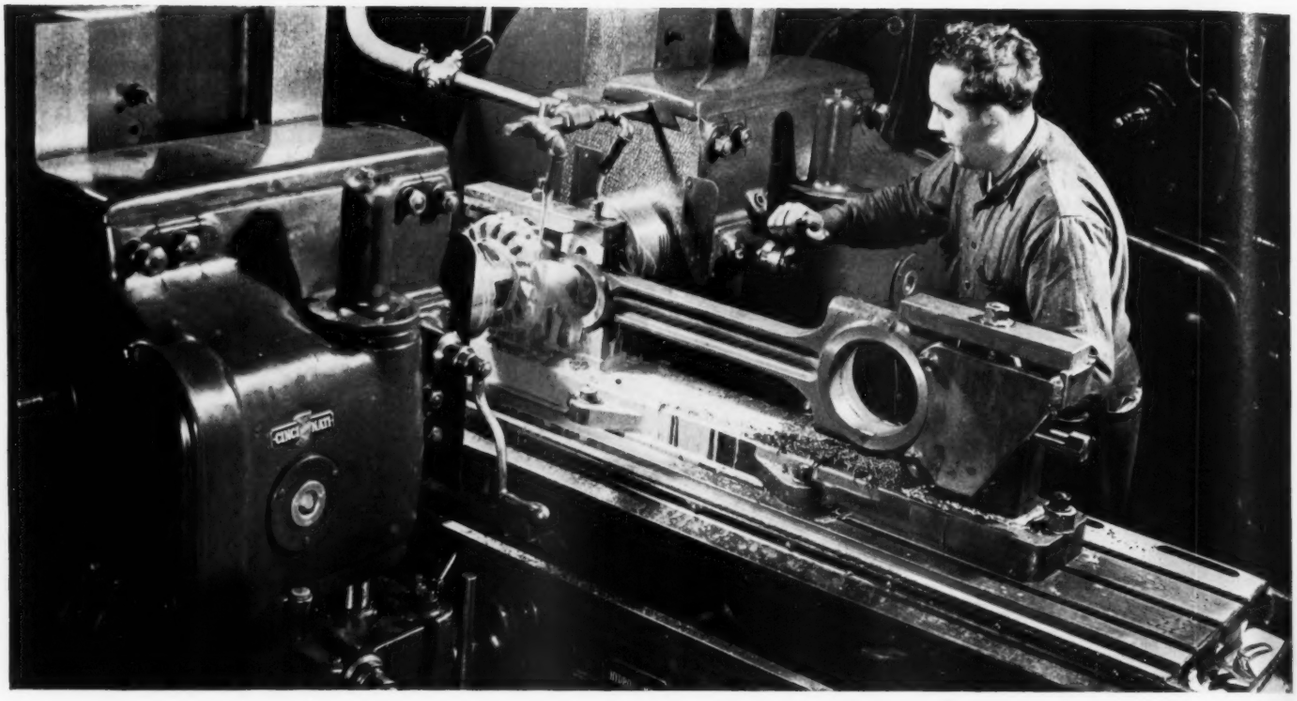


Stress-strain characteristics of Koroseal, synthetic rubber, and a natural rubber adapted for service in oil

Sealing member of Koroseal on reciprocating piston. Koroseal compounds tend to shrink in presence of oils, improving sealing characteristics in such applications. Shrinkage increases slightly as temperature is raised but original physical properties are maintained. Shrinkage is caused by slight tendency of plasticizer to dissolve

Three forms of processed Koroseal: a sheet of batch stock, tubing, and thin sheet

Gaskets stamped out of solid sheets of Koroseal provide resistance against oils



HYDRAULIC CIRCUITS

For Controlling Rate of Feed in Machines

ALBERT H. DALL
Research Department, Cincinnati Milling Machine Company

ONE OF THE principal uses of hydraulics in machine tool design is in feed rate control. For controlling feeds hydraulic systems are usually superior to mechanical systems in that the rates are infinitely variable between the maximum rate and zero. In addition to this decided advantage, the rate control can be made extremely convenient, economical and simple. On the other hand, from the standpoint of power, well designed mechanical feed controls may be somewhat more efficient than hydraulic controls and may also, in special applications, offer the secondary advantage of enabling a shift from one speed to another without passing through the intermediate speeds. However, in the majority of applications, the hydraulic designs offer advantages which outweigh those of the mechanical designs.

Hydraulic feed rate control systems can be divided into two types: (1) throttle type circuit; (2) variable delivery pump circuit.

The throttle type circuit employs the constant delivery pump, usually of the gear or vane type, for its source of hydraulic energy. These pumps have the advantage of being simple in design and economical to manufacture. The output of the pump is constant in volume and is usually maintained at a constant pressure through the use of a pressure regulating or relief valve. Thus the output of the pump is substantially constant in energy, giving rise to the necessity of discarding part of this energy when the system is operating at feed rates other than the maximum as determined by the throttle valve opening. It follows, therefore that any variable feed rate hydraulic system using a constant delivery pump and a throttle valve for feed regulation must employ means of shunting the excess fluid. This is usually accomplished by means of a shunt through the pressure regulating valve. Fig. 1 shows schematically a simple throttling circuit with the throttle in the forward pressure line.

An analysis of the pressure relations where

W = work resistance in lb.
P_1 = fluid forward pressure in lb. per sq. in.
A = piston area in sq. in.
P_2 = fluid back pressure in lb. per sq. in.

shows $W = (P_1 - P_2)\,A$, but $P_2 = 0$ (1)

therefore: $W = P_1 A$ (2)

Using the electrical analogy (Ernst, *Product Engineering*, April and May 1935), in which resistance to flow of a viscous fluid in a circuit is treated as an entity, so that

$$\textit{Pressure drop} = \textit{Quantity} \times \textit{Resistance Unit} \quad (3)$$

$$\text{or } \textit{Quantity} = \frac{\textit{Pressure drop}}{\textit{Resistance Unit}} \quad (3a)$$

This expression establishes the resistance as an independent variable which is determined by particular circuit conditions, and the pressure drop becomes the dependent variable the value of which is the result of forcing the quantity Q through the particular resistance. Thus when unit flow produces unit pressure drop the fluid has encountered unit resistance.

Thus as in electrical circuits, numerical values for hydraulic resistance are established, and the resistance required

for a desired pressure drop is calculated. Using the common pressure and quantity units, the value of the resistance unit for an element in the circuit, or a branch of the circuit can be calculated from the relationship:

$$\text{Resistance units} = \frac{\text{pressure drop in lb. per sq. in.}}{\text{flow in cu. in. per min.}} \quad (4)$$

Let q_1 = flow in cu. in. per min. through throttle

R = resistance of throttle, in "units" (as determined by test under standardized conditions, or by calculation from physical dimensions)

P_0 = pump pressure in lb. per sq. in. (maintained at constant value by means of the pressure regulating valve)

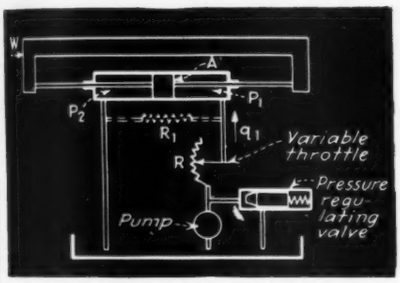


Fig. 1—Feed circuit which uses a constant delivery pump and a throttle valve in forward pressure line

Then from Equation (3a) the flow through the throttle is,

$$q_1 = \frac{P_0 - P_1}{R} \quad (5)$$

And by substituting Equation (2) in Equation (5)

$$q_1 = \frac{P_0 - \frac{W}{A}}{R} \quad (6)$$

From this equation, it is apparent that the feed rate $\frac{q_1}{A}$ (which varies directly as q_1) is influenced by W the work resistance. The rate of change of feed rate with respect to work resistance, all other conditions remaining constant is,

$$\frac{dq_1}{dW} = -\frac{1}{AR} \quad (7)$$

The effect of a given change in feed rate, however, depends on the magnitude of the feed rate before the change; in other words, it is the percentage change in feed rate that is important and not the feed rate change itself. Therefore, the performance criterion to be considered is,

$$\frac{dq_1}{dW} \times \frac{1}{q_1} = -\frac{1}{AR} \cdot \frac{1}{q_1} \quad (7a)$$

Substitution of (5) in (7a) results in,

$$\frac{dq_1}{dW} \times \frac{1}{q_1} = -\frac{1}{A(P_0 - P_1)} \quad (7b)$$

Thus the percentage change in feed rate is affected inversely by the area of the piston and the pressure drop across the throttle. This design criterion indicates that the area of piston and pressure drop across the throttle should be made as large as is practical to minimize the effect of work resistance change upon feed rate.

In the foregoing analysis, as well as in the analyses of circuits subsequently described in this article, the effects of leakages are neglected in order to avoid undue complication and lengthy description. It is interesting to note, however, that this method of analysis—where resistance is treated as an entity—is particularly applicable to leakage problems, where the flow is usually of the laminar or streamline type, and where complex systems of resistances both in series and parallel are often encountered.

For example, in Fig. 1, a leakage out of the forward pressure line through resistances R_1 will affect Equation (6) to read

$$q_1 = \frac{P_0 - \frac{W}{A}}{R} - \frac{W}{AR_1} \quad (7c)$$

where R_1 is leakage resistance in the same units as R (the throttle resistance). Consequently Equation (7) will become,

$$\frac{dq_1}{dW} = -\frac{1}{A}\left(\frac{1}{R} + \frac{1}{R_1}\right) \quad (7d)$$

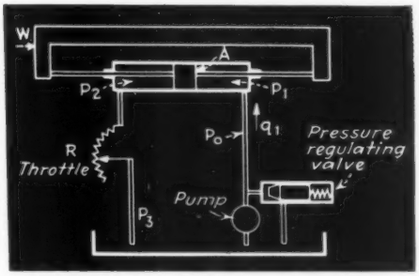


Fig. 2—Hydraulic circuit with a constant delivery pump and a throttle valve in back pressure line

The percentage change in feed rate with respect to the change in work resistance, therefore, is,

$$\frac{dq_1}{dW} \times \frac{1}{q_1} = -\frac{1}{A\left[P_0\left(\frac{R_1}{R_1+R}\right) - P_1\right]} \quad (7e)$$

The leakage factor $\frac{R_1}{R_1 + R}$ will approach unity as the leakage resistance approaches infinity. Thus Equation (7e) agrees with Equation (7b) for the case of infinite leakage resistance.

An inspection of Equation (7e) reveals that when R (the throttle resistance) is small, the leakage correction factor $\frac{R_1}{R_1 + R}$ has little effect while for higher values of R the correction factor will have the effect of increasing the value of the right hand side of the equation thus showing that leakage has a greater percentage effect at the lower feed rates than at the higher rates.

When

$$P_0\left[\frac{R_1}{R_1+R}\right] = P_1 \quad (7f)$$

the percentage change in feed rate will be infinity causing a cessation of motion. By using Equation (3a) this result can be obtained by setting $q_1 = 0$ and regarding R and R_1 as series resistances.

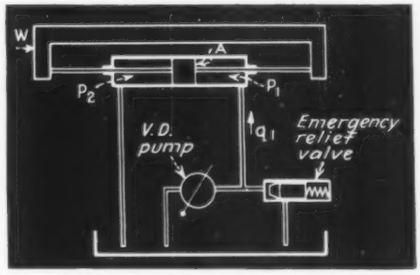


Fig. 3—Variable displacement pump circuit in which the feed rate is varied by changing the pump displacement

In like manner, the effects of leakage can be analyzed in other circuits hereafter. In some circuits leakages will cause an increase in feed rate (leakage out of back pressure line shown in Fig. 5 and 6) while in others, the effect is a decrease in feed rate.

A throttling circuit with the throttle in the back pressure line is shown in Fig. 2. In this circuit the forward pressure is held constant while the back pressure varies with work load. An analysis of the pressure and flow relations shows that

$$P_0 = P_1 \quad (8)$$

$$W = (P_1 - P_2)A = (P_0 - P_2)A$$

$$q_1 = \frac{P_2 - P_3}{R} \quad (9)$$

$$\text{When } P_3 = 0,\ q_1 = \frac{P_2}{R} \quad (10)$$

$$P_2 = P_0 - \frac{W}{A}$$

which substituted in Equation (9) gives

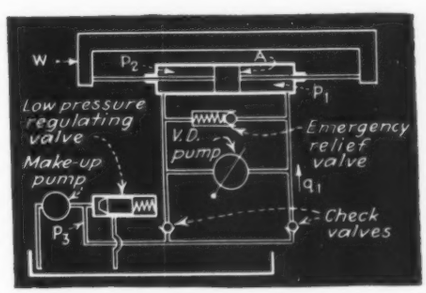


Fig. 4—Negative work loads can be supported in this variable displacement pump circuit with a leakage make-up pump

$$q_1 = \frac{P_0 - \frac{W}{A}}{R} \qquad (11)$$

Equations (6) and (11) are identical, which proves that the feed rate varies with work resistance, forward pressure, and throttle resistance; in the same manner for both circuits. However, there is a distinction between the two circuits in that the circuit with the throttle in the back pressure line is capable of supporting negative work resistance, while it is obvious that the back pressure in the first circuit will never rise above zero gage pressure. For the circuit shown in Fig. 2, when the load W is in the direction of feed Equation (11) becomes

$$q_1 = \frac{P_0 + \frac{W}{A}}{R} \qquad (12)$$

In the variable displacement pump type circuit, the feed rate is varied by changing the pump displacement. The simplest example of this type is shown in Fig. 3. In this circuit the forward pressure P_1 is determined only by the work resistance W. The flow q_1 is independent of the pressure except for the change in pump slip which in a well made variable displacement pump is almost negligible. When the work resistance is in the same direction as the table motion, the back pressure cannot build up and therefore this type of load would be unsupported.

A variable delivery pump circuit which is capable of supporting negative work loads is shown in Fig. 4. In this circuit, the return fluid enters the intake side of the pump. This type of circuit is designated a closed circuit. In a closed circuit, means must be provided to make up for leakage out of the system. In Fig. 4, check valves are shown connected to both forward and back pressure lines. When either the forward or back pressure line

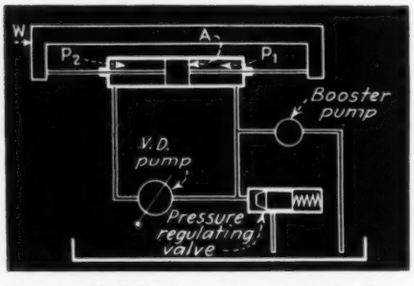


Fig. 5—Modification of variable displacement pump closed circuit with "booster" pump in the forward pressure line

tends to become slightly evacuated through leakage, the pressure will drop because compression is lost. Whenever the pressure in either of these lines drops below the pressure determined by the make-up pump relief valve, the check valve will raise and fluid will be admitted to make up the leakage. Thus, the datum pressure level of the system must be the

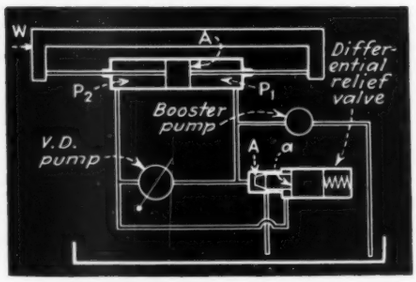


Fig. 6—Locked circuit which employs a differential relief valve, Cincinnati Milling Machine patent, permits a complementary pressure rise and fall in both forward and back pressure lines

make-up pump pressure. The system fails only when the leakage exceeds the delivery of the make-up pump.

This system can be made exactly symmetrical by placing another emergency relief valve between the forward and back pressure line. Obviously a reversing valve may be introduced between the pump and cylinder to control the direction of the table motion. The relation between the pressure and work resistance is simply

$$W = (P_1 - P_2)\ A \qquad (13)$$

where for negative work resistance, P_2 can exceed P_1. In this system the forward pressure is limited only by the setting of the emergency relief valve, while the back pressure may reach any value.

Another modification of the variable delivery pump closed circuit is shown in Fig. 5. In this circuit the make-up pump delivers fluid to the forward line and is designated by the term "booster" pump. The booster pump in this circuit is a small capacity, high pressure pump which delivers its entire output to the forward pressure line. Except for leakage, the entire delivery from the booster pump is forced out of the pressure regulating valve, thus keeping the forward pressure constant regardless of the work load W. The back pressure varies to accommodate changes in work load by reason of changes in compression in the back pressure line. Thus, under a small load, the piston will accelerate to compress the fluid in the back pressure line until the proper pressure is reached to balance the load. It follows, therefore, that in both circuits, Figs. 4 and Fig. 5, the pump and its drive must be of such design that overrun will not result under conditions of negative work resistance.

The "locked circuit," shown in Fig. 6 (Cincinnati Milling Machine patent) employs a differential relief valve which permits a complementary rise and fall in both forward and back pressure lines. The differential relief valve has a small differential area which is connected to the back pressure in addition to the normal connection of forward pressure to the valve.

For equilibrium, the forward pressure P_1 times the area A plus the back pressure P_2 times a must equal the opposing spring pressure S. Thus,

$$P_1A + P_2a = S \qquad (14)$$

Let the ratio of areas be

$$\frac{A}{a} = n \qquad (15)$$

then

$$nP_1 + P_2 = \frac{nS}{A} \qquad (16)$$

For simplicity let $n = 1$, then

$$P_1 + P_2 = \frac{S}{a} \qquad (17)$$

Therefore, the sum of the forward and back pressures must remain constant. A rise in forward pressure must be accompanied by a drop in the back pressure and vice versa. Fig. 7 shows graphically the result when the pressures P_1 and P_2 are plotted against work resistance.

The differential relief valve may be housed in a unit which incorporates also the booster pump, rapid traverse gear pump, and the various valves which control the flow to the feed cylinder.

Design Considerations

The choice of the type of feed rate control system must be governed by requirements of the system in service. Where large variations in work resistance occur, a variable delivery pump system would

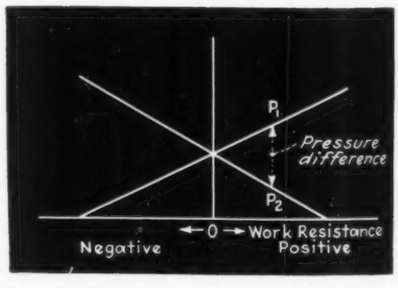


Fig. 7—Forward and back pressures plotted against work resistance to illustrate complementary pressure rise and fall in Fig. 6 circuit

be indicated. However, if the variations in feed rates are not an important consideration the economy and simplicity of the throttle system should be favored.

The smoothness of feed rate is determined by detail design. For example, certain types of relief valves have an inclination to vibrate, which is reflected in the system by a lack of smoothness. Other details, such as valve porting and hydraulic balance may have a deleterious effect on smoothness of motion. The importance of slight variations in pump delivery are often overestimated, since accumulator effects are almost invariably present in all systems.

Hydraulic feed rate control design, therefore, is not exempt from the vagaries of design techniques, although in general, the technique is simple since the ultimate design usually lacks complexity

WHAT IS INVENTION—III

H. A. TOULMIN, JR.
Toulmin & Toulmin

PERSISTENCY AS PROOF. Those who abandon their efforts before achieving a successful invention are not inventors and all their efforts go for nothing as against the one who starts where they left off and takes the final steps, no matter how slight, to success.

On the other hand, the courts take into consideration, in determining whether the final steps constitute invention, the persistency with which experiments have been prosecuted. The scope and length of the experiments, the failures the inventor encounters and the amount of money he spends are all taken into account. In this connection the Supreme Court of the United States said in one case: "In view of the fact that previous attempts, of which there appear to have been several, to make a practical canvas belt, had been failures, and that Gandy had been experimenting with the subject for several years before he discovered that a change was necessary in the structure of the canvas itself, we do not think his improvement is a change in degree only, or such a one as would have occurred to any ordinary mechanic, and our opinion is that it does involve an exercise of the inventive faculty. The change is such as would only have occurred to one familiar, not alone with the impossibility of making a practical belt out of ordinary canvas, but to one who had bestowed considerable thought upon the method of overcoming the difficulty."

Imitation as a proof. In my book, "Invention and the Law," I say under this heading: "The fact that persons other than the inventor prefer to adopt his invention rather than utilize what already is open to them, is proof of invention. Where prior art patents and publications and prior uses in the art are old and public property, the fact that the alleged infringer prefers to risk a lawsuit and appropriate the invention of the patentee is strong evidence that such a patent covers an invention. This is true despite the fact that the defendant claims the advance of the inventor is of such minor character as not to be worthy of any protection.

"In determining invention, the courts use as one of the tests the standard of its acceptance by reasonable business men. Business men do not adopt an invention without reason, when, by not adopting it, they can get equal results and avoid the expense of litigation."

One court said in the connection: "The imitation of a thing patented by a defendant, who denies invention, has often been regarded . . . as conclusive evidence of what the defendant thinks of the patent, and persuasive of what the rest of the world ought to think."

In another case: "But the vital thought of using a reciprocating engine which through one rack bar accomplished the driving of both screws was new. The solution was simple, when discovered, but had not before been obvious to the skilled mechanic, as evidenced, not only by Lower's frequent experiments, before the desired result was accomplished, but also the pronounced success of the device and (after its successful use by Lower) its adoption by Hanna, the active competitor of Lower, who had before rejected or abandoned the idea of a reciprocating engine for a two-cylinder engine."

Unsatisfied public demand. The most practical proof of the utility and novelty of an invention is whether there was previously an unsatisfied public demand for such a device, or for a certain result which the invention achieves. Proof of such an unsatisfied general demand, and the extent and nature of the use of the device as a result of meeting that demand, is seriously taken into account by the courts in determining whether there has been patentable invention.

Even the fact that a patent case has come into court has a bearing, as is shown by the following excerpt from an opinion of the Supreme Court of the United States: "The extent of this litigation attests at least the utility of the process supposed to be described in the patent, as it shows and measures the extent of the public demand for its use."

In another case the same court said: "We have taken for granted in our discussion that the Grant tire immediately established and has ever since maintained its supremacy over all other rubber tires and has been commercially successful while they have been failures. The assumption is justified by the concession of counsel."

Public acquiescence in validity. Here we have one of those quirks in the law which sometimes make it seem, to the layman, highly inconsistent. In a preceding paragraph we saw that the willingness of a party to run the risk of costly infringement suits by imitating another's patented product is considered by the courts to be excellent proof that the patent covered a real invention.

But, on the other hand, the courts have frequently held that absence of trespassing on a patentee's rights is one of the strongest tests of novelty of invention, for it indicates that that part of the public which is familiar with the art has accepted the patent as valid. Even stronger than lack of infringement is failure of anyone over a period of years to contest the validity of the patent.

In one case, which happens to cover a process, the court made this decision which applies as well to any article of manufacture or machine: "The record shows not only that the process in suit was promptly considered by the patentees as an original and important discovery, but that it was immediately generally accepted as so great an advance over any process known before that, without puffing or other business exploitation, it promptly came into extensive use for the concentration of ores in most, if not all, of the principal mining countries of the world . . . and that, because of its economy and simplicity, it has largely replaced all earlier processes. This, of itself, is persuasive evidence of that invention which it is the purpose of the patent laws to reward and protect."

In another case the court said: "The fact is that for nearly ten years before the bill in this cause was filed the appellants sold in the country a smokeless granulated gunpowder, as a product protected by the letters patent which the appellee now insists are void for obscurity of language. Never until this cause was instituted, so far as we are informed, was the validity of the patent disputed. During all that period of ten years there seems to have been a public acquiescence in its validity. With these facts before us, we think we are not justified in holding the first claim of the patent to be invalid."

Experimentation. The fact that an inventor has engaged in long experimentation prior to his discovery is indication that it was not an easy and obvious thing to accomplish, and that therefore true invention is involved.

Here are excerpts from two decisions bearing on this: ". . . it is regarded as significant that there has been a recognized need for such a machine, and that the efforts of others to meet it have been without success, which the inventor has attained only after continued experiment."

Again: "The proof satisfies us that the device of Hopkins was not a mere adap-

tation of existing contrivances, but came as an unexpected surprise at the end of earnest study of the subtle problems involved in this art."

Either a machine or the product made by it may be patented. No comment is needed on the following decision, except to point out that a wise choice should be made and if possible both patented.

The court said in the case of Rubber Co. v. Goodyear: "Patentable subjects, as defined by the patent law, are 'any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvement on any art, machine, manufacturing, or composition of matter.' A machine may be new and the product or manufacture proceeding from it may be old. In that case the former would be patentable and the latter not. The machine may be substantially old and the product new. In that event the latter, and not the former, would be patentable. Both may be new, or both may be old. In the former case, both would be patentable; in the latter neither. . . . The patentability, or the issuing of a patent as to one, in nowise affects the rights of the inventor or discoverer in respect to the other. They are wholly disconnected and independent facts. Such is the sound and necessary construction of the statute."

Change of form. If change of form produces a new mode of operation or secures a new and useful result it is invention. But the change of form must produce something not naturally to be expected, for it is assumed that natural results from well-known forms are part of the common store of knowledge.

In one case the court said: "To change the form of an existing machine, and by means of such change to introduce and employ other mechanical principles or natural powers, or, as it is termed, a new mode of operation, and thus attain a new and useful result, is the subject of a patent."

In the case of Hammond Buckle Co., v. Goodyear Rubber Co., the court elaborated upon this, as follows: "The substitution of the bifurcations for the unbifurcated tongue plate, rearwardly extended, as in the Blackman patent, was a mere change of form: and unless such change of form accomplishes something —introduces a new function, or a new method of performing the old function with greater excellence or economy—it is not patentable invention. The bifurcation does not accomplish anything new in the way of more efficient support. The function of supporting the catch-plate, and the mode of supporting, are entirely unaffected by the diversity of shape. The bifurcation does, however, subserve a useful purpose, which is described in the patent as follows:

"'The bifurcations at the rear end of the tongue plate have a slight lateral elasticity, and the tongue is made at the point *e* slightly broader than elsewhere; and its breadth is such that it must, in locking and unlocking the tongue, pass through said bifurcation, by springing the forks thereof apart. This insures a slight locking action, both when the tongue is opened and when it is closed.'

"This additional element develops a function in the bifurcations which may be said to involve an exercise of the creative faculties, and thus the entire combination, being apparently new in the art, may be patentable."

Change of proportions. If the difference between success and failure depend upon the choice of proportions, a change of proportions may constitute patentable invention, provided the change does not merely make for convenience, appearance, size or adaptability. It must be of the essence of the workability of the device.

An excellent example of this had to do with incandescent lamp filaments. The court said: "Although all-glass globes, with leading-in wires passing through the glass and sealed into it, had been used before to preserve the condition of the interior of a chamber from the effects of leakage at the joints, and although the prior art, including the French patent, indicated that subdivision of the electric light was to be obtained by the use of burners of high resistance and small radiating surface, and although pencils of carbon had been tried in imperfect *vacua*, and found wanting, it was invention, in view of the teachings of the art as to the disintegration of carbon under the action of an electric current, to still select that substance as suitable material from which to construct a burner much more attenuated than had ever been used before, reduced in size to the filamentary form in which economy of construction requires that it must be used in order to avail of the philosophy of high resistance and small radiating surface, and so to combine old elements that the disintegration due to 'air washing' should be practically eliminated, and the burner thus become commercially stable."

Commercial success. If an invention has met with notable commercial success, without undue sales or advertising effort, the presumption is that the patent is valid providing of course that it meets the tests of novelty and usefulness. In questions where there is doubt, commercial success is often relied upon to tip the scales.

In one case the courts held: "It is enough to say that to enter an art crowded with a multitude of similar forms and secure an immediate and notable success is in itself sufficient evidence of invention and conclusive evidence of novelty."

In the case of Motor Improvements v. General Motors Corporation the court held: "While this is an industry in which the purchasing public may be largely ignorant of mechanical devices, and keenly competing manufacturers doubtless are ready to adopt comparatively inexpensive additions that furnish new and attractive talking points for their extensive advertising, nevertheless the ready and quick adoption of Sweetland's filter, after it had been thoroughly tested by defendants, weighs heavily in case of doubt as between utility and nonutility, invention and mere mechanical advance."

On the other hand, the Supreme Court of the United States has said: "The argument drawn from the commercial success of a patented article is not always to be relied on. Other causes, such as the enterprise of the vendors, and the resort to lavish expenditures in advertising, may co-operate to promote a large marketable demand."

EDITOR'S NOTE: This installment concludes the series of three articles in which have been set forth an exposition of the positive rather than the negative aspects of new and useful ideas that may be patentable, and also considerations of the conditions surrounding the idea that are often reviewed when granting patents for inventions. Part I and Part II appeared in *Product Engineering* in the February and June numbers respectively.

•

Current Quotations

"The importance of safety education and safety campaign in our shops cannot be over-estimated. There are two major considerations: first, we owe it to our employees to preserve their health and their full faculties: any industry that fails to safeguard its employees is certainly not deserving of true managerial respect. The only safeguard is eternal vigilance on the part of management to keep the equipment in perfect shape and to supply all necessary safety protections; then eternal education to keep the workmen using the protections offered and taking no chances."—E. S. SAWTELLE, *vice-president, Tool Steel Gear and Pinion Company, in an address before the American Gear Manufacturers' Association, at Virginia Beach, Va., May 15, 1939.*

FURNACE BRAZED JOINTS

For Parts Made of Non-Ferrous Materials

HERMAN H. SCHMITT
Westinghouse Electric & Manufacturing Company

ELECTRIC FURNACE brazing is a comparatively new method of joining metals, and so far has been applied principally to steels. But furnace brazing also can improve the quality and can lower manufacturing costs of many non-ferrous parts. The principles involved in the process are the same as those for steels, but the technique is somewhat different because of some metallurgical factors.

In non-ferrous brazing, as in the copper brazing of steel, a sheet, wire, or paint of the brazing material is placed near the joints to be brazed. The parts when assembled are passed through an electric furnace in which a protective atmosphere prevents oxidation and which also removes or cleans any light oxide films that might cover the metal surfaces. The surface is thus prepared for wetting by the molten brazing alloy so that the alloy can be drawn into the joints by capillary action and become alloyed with the parent metal. The piece is then transferred to a cooling chamber in which the alloys solidify and form strong joints.

In carrying out this process, however, the conditions are somewhat less advantageous than in the copper brazing of steel. First, eutectics between the metals joined (if different) or between one or more of the metals joined and the brazing alloy must be considered in selecting the proper brazing alloy and in determining a workable operating temperature. To illustrate the importance of this point, the simple operation of joining silver to copper may be cited. Silver melts at 960 deg. C. (1,761 deg. F.) and copper melts at 1,083 deg. C. (1,981 deg. F.). On first thought a brazing alloy which melts at or near 800 deg. C. (1,472 deg. F.) might be selected. With metal-to-metal contact between silver and copper at a temperature of 800 deg. C. (1,472 deg. F.), however, a eutectic alloy melting at 780 deg. C. (1,436 deg. F.) would form and thus fuse and destroy the part.

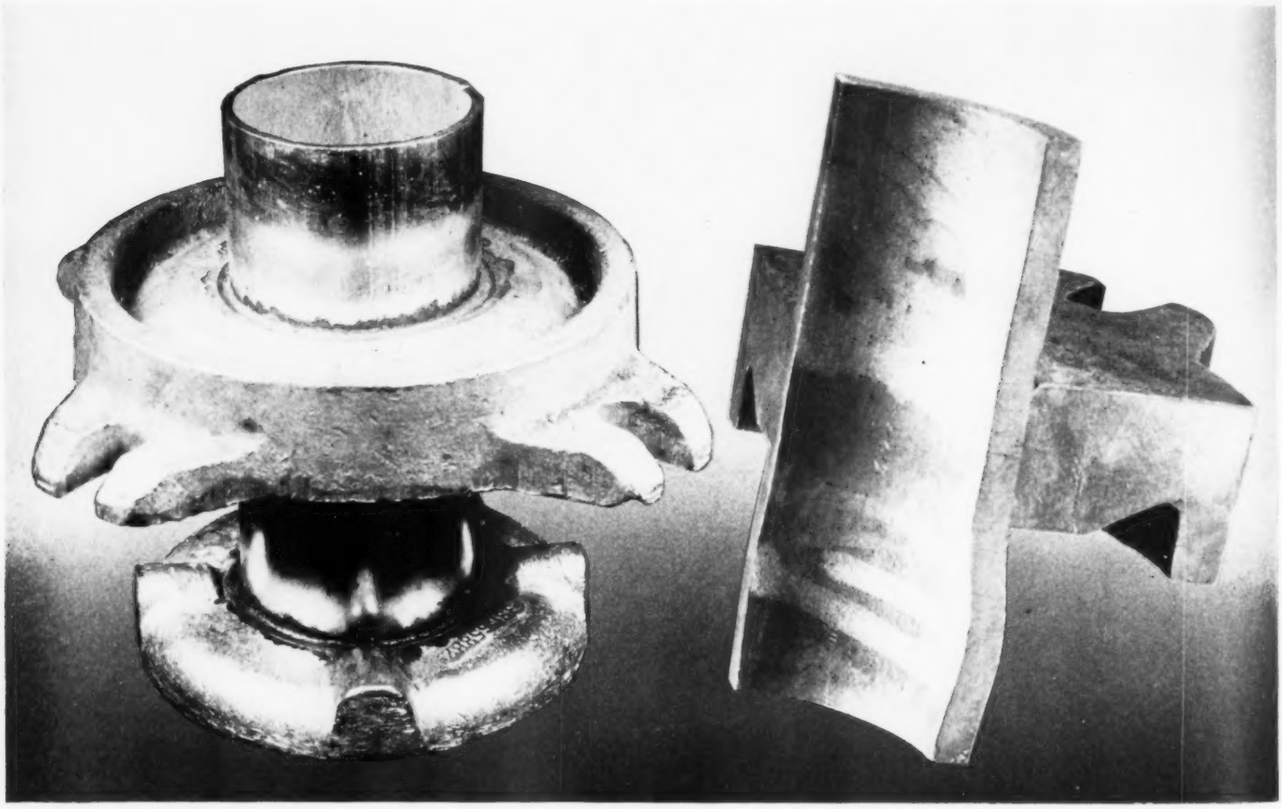
Furthermore, copper wets and spreads actively over steel, because of the relatively low solubility and diffusion rate of copper into steel. Non-ferrous metals, on the contrary, are poorer in their wetting and spreading action, because of the generally highly mutual solubility of two such in each other, and likewise their higher diffusion rates. For this reason, it is necessary to place the brazing alloy close to the joint and hold it there in the molten state to permit penetration of

the joint. Frequently counterboring to accommodate a wire ring of the brazing alloy serves the double purpose of holding the brazing alloy in place directly at the joint, and also of providing a reservoir of the molten brazing alloy.

In order to prevent the hydrogen embrittlement of commercial tough pitch copper parts it is necessary to maintain an atmosphere containing very little or no carbon monoxide (CO) or hydrogen (H_2). With only very low concentration of these reducing agents it usually may be necessary to apply flux to the non-ferrous parts to prevent the formation of a surface film that would retard the wetting action of the brazing alloy. Rapid heating and comparatively short brazing cycles are necessary for brass parts to prevent excessive volatilization of zinc.

In non-ferrous brazing the temperatures usually are near the plastic range of the part, and supporting fixtures may be necessary to prevent collapse and distortion of the assemblies. However, none of these problems is insurmountable, and the process, if fully understood, may be applied as advantageously as the older copper brazing process for steel parts.

To illustrate the possibilities of brazing non-ferrous parts in an electric furnace, typical examples of how the process has been adopted in production are shown in several figures. Both of the furnace brazing applications here described have resulted in stronger, cleaner parts at lower manufacturing costs, and may possibly point the way to other applications of furnace brazing for joining non-ferrous parts that could be done with profit and further improvement in ability to stand up in service.



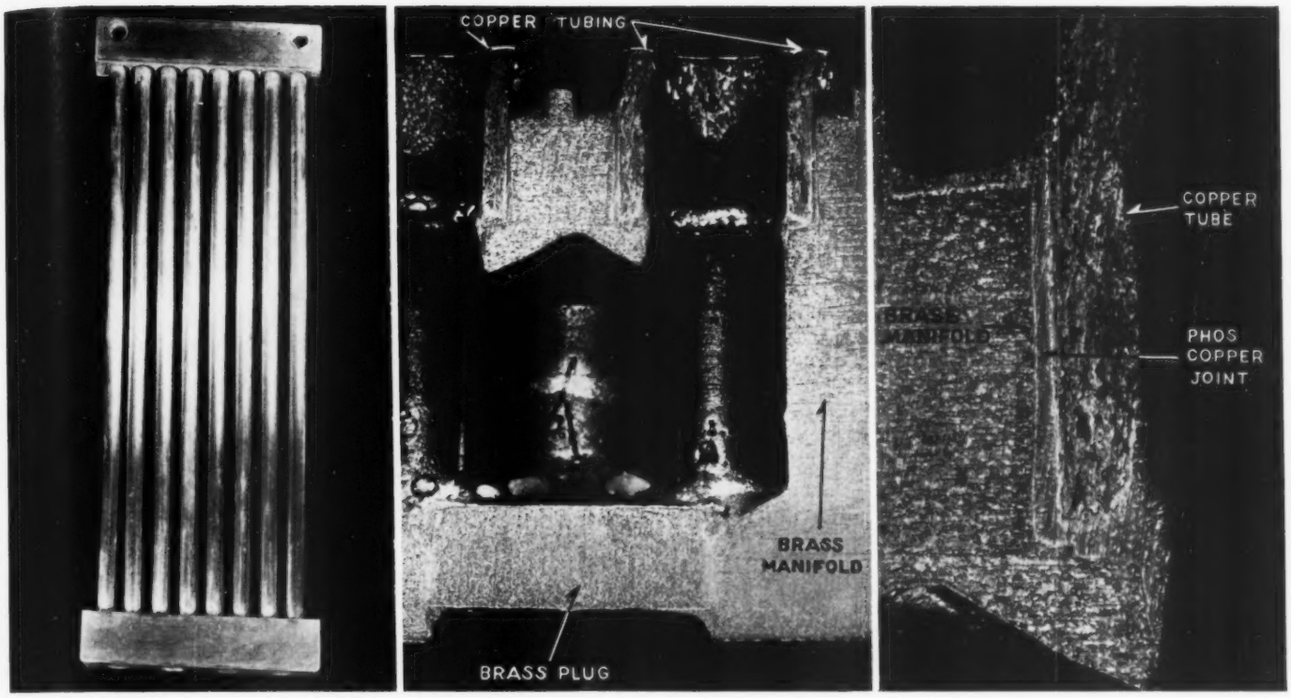
Condenser-bushing flange, composed of a yellow brass tube (65 per cent copper, 35 per cent zinc) and two bronze castings, (85 per cent copper, 5 per cent lead, 5 per cent tin, and 5 per cent zinc). This part formerly was threaded and soldered manually with a tin-lead solder, but is now being furnace brazed with a brazing alloy composed of 7 per cent phosphorus and 93 per cent copper, known to the trade as "Phos-Copper." The brass tubing is standard stock of 3 in. outside diam., $2^3/_4$ in. inside diam., and $7^1/_2$ in. long.

The bronze pieces are sand cast to shape and bored to press with 0.003 in. interference onto the brass tubing. At the end on which the brazing alloy rests —the top end in the furnace—the castings are counterbored $^1/_4$ in. larger in diameter than the bore, to a depth of $^1/_8$ in. A Phos-Copper wire $^1/_8$ in. in diam. is wound into a ring that fits snugly on the brass tube, and is pressed into this counterbored section. On this same end of the large casting a bore 0.004 in. larger in diameter than the "press fit" is cut to a depth of $^3/_8$ in. This enables the brazing alloy to start into the joint, thereby increasing the sealing action and the strength, and also increasing the rate of penetration through the "press fit."

Next the parts thus machined are bright dipped in a solution of nitric and sulphuric acids carefully fluxed with a material known as "Fluxine" paste, then assembled by pressing the castings into place on the brass tube. The Phos-Copper rings are pressed into the counter-bored section and the assembly is ready for furnace brazing. The brazing for these parts is done at 825 deg. C. (1,515 deg. F.) and the parts are held at that temperature for five minutes. The total brazing cycle (time in the hot zone of the furnace) is approximately 20 minutes. This part is placed in the furnace and brazed in the vertical position as shown.

The parts as removed from the furnace cooling chamber are clean, reasonably free of flux and when tested with air pressure at 30 lb. per sq. in., showed a very small percentage of "leakers." Leaks usually are caused by castings faults.

A section of a condenser-bushing flange which was subjected to a load of 40,000 lb., is shown in the right hand illustration above, and although the tube buckled, the joint is still intact. In this example a neater part was produced by electric furnace brazing and cost reductions were realized on items such as (*a*) by eliminating threads a thinner wall section was possible and less weight of brass tube was required, (*b*) a costly threading operation was eliminated, (*c*) an extra annealing operation was eliminated since heating for brazing constitutes an annealing treatment.

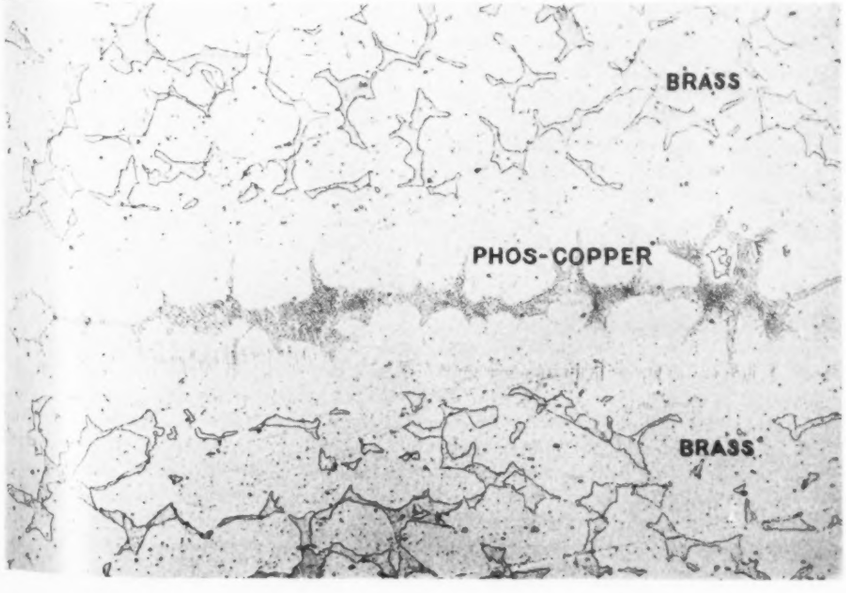


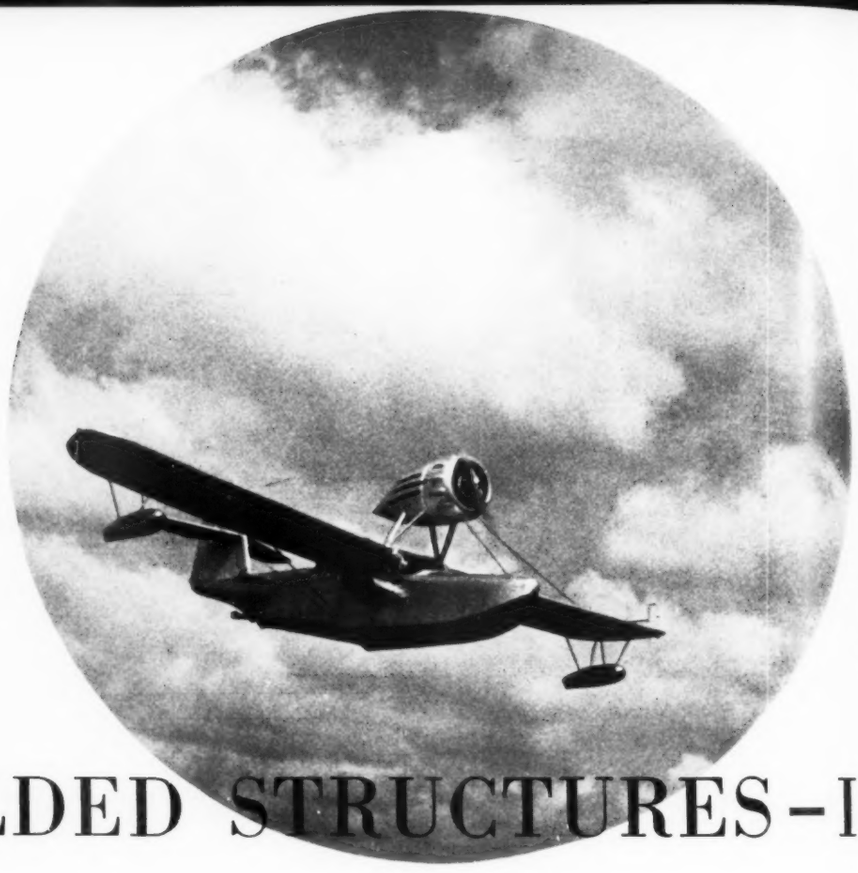
Oil-cooling unit which was formerly hand torch brazed but now furnace brazed. The part consists of eight oxygen-free, high-conductivity copper tubes having inside diameters of 0.259 in. outside diam. of 0.344 in., and lengths of 11½ in. brazed into brass manifold sections. These manifold sections are machined from yellow brass (62 per cent copper, 3 per cent lead, 35 per cent zinc) bars 0.625 by 1.0 by 4.625 in. in size. The construction of this manifold is shown in detail in the center illustration above which shows a polished and etched micro-section of one of the manifold chambers after being furnace brazed.

These units are so constructed that the water passes through all of the tubes in series. The brass blocks are drilled for a snug fit on the copper tubing and then counterbored ⅛ in. larger in diam. than the outside diam. of the copper tubing to a depth of ⅛ in. Phos-Copper rings (0.344 in. inside diam.) made of wire ⅛ in. in diam. are pressed into the counterbored section. The brass bars are drilled on one side to accommodate eight copper tubes. On the opposite side one of the bars is drilled with four holes ½ in. in diam. and the other bar with three ½-in. holes. The ½-in. holes are drilled on the exact centers between the copper tubes and as the drill progresses through the bar it removes one-half of the wall section of the adjoining cavities and forms a continuous path from one copper tube to the other. The manifold block containing three holes is drilled for an outlet and inlet chamber and in this manner allows the water to pass from one tube to the next in series.

The finished machined parts are cleaned by bright dipping in a solution of nitric and sulphuric acid, carefully fluxed, then assembled by placing the eight copper tubes into the smaller tubes. The manifold is completed by sealing the large drilled holes with the brass plugs which are pressed into position. Over these plugs are then placed Phos-Copper rings with an outside diam. of ½ in. made of ⅛-in. wire. The cooling unit thus assembled is properly aligned in a brazing fixture to prevent distortion, and is placed in the furnace.

Assembled part and fixture are placed directly into the furnace chamber at 825 deg. C. (1,515 deg. F.) and held at that temperature for five minutes, the total time in the hot zone being approximately twenty minutes. The Phos-Copper rings which are held in place by the counterbored section around the copper tubes and the shoulders adjacent to the brass plugs, melt and flow into the joints leaving neat fillets. Unlike the flanges for condenser bushings, this part is furnace brazed in the horizontal position. Fillets of great uniformity result from the process. The right hand illustration above shows the joint between the copper tube and the brass manifold, the brazing alloy may be seen to have crept under the end of the copper tube thus making an excellent seal. A microphotograph of this joint between the brass sealing plug and the brass manifold is shown in the lower left hand illustration.





SEA BIRD—*A stainless steel amphibian by Fleetwings, Inc.*

SPOT-WELDED STRUCTURES—I

Designed for Stainless Steel

G. G. CUDHEA
Fleetwings, Inc.

ELECTRIC RESISTANCE welding has a number of advantages from the cost standpoint. No preliminary preparation such as punching rivet holes, are required. Spot welding can be done much faster than riveting, the automatic machines for welding being faster and simpler to operate than riveting machines. An inexperienced workman can be trained to operate spot welding machinery in a relatively short time.

An advantage from a structural or design standpoint is that spot welds can be spaced at a much closer pitch than can rivets and the flange required is smaller than that needed for rivets. The closer pitch increases the compressive efficiency of free flanges and the smaller flanges required reduce the amount of material necessary in the relatively inefficient free flange. Also, spot welded joints can be designed to attain 100 per cent efficiency since no metal is removed as in punching rivet holes. Fittings, because of the closer pitch available, can be made lighter and smaller when spot welded. Further, since the cost of a few additional spot welds is low, joints can be designed for high margins of safety at a very slight additional labor cost, and with no additional structural weight penalty.

From an aerodynamic point of view, the absence of rivet heads lessens the drag of the metal aircraft wing coverings. Here again the close pitch permits fabrication of wing coverings which retain their contours and do not develop the usual diagonal tension field wrinkles.

With reference to the material used for welded airplane structures, stainless steel has many advantages. Being corrosion resistant, closed or hollow sections are permissible. It is adaptable to spot welding because of its high electric resistance and low thermal conductivity; the former lessening the required current, the latter concentrating the fusion heat during welding. The low current requirements permit the use of relatively light secondary leads and facilitates the use of small hand and portable welding tools.

Type of Stainless Used

High tensile stainless steel strip and sheet with an ultimate tensile strength as high as 185,000 lb. per sq.in., yield point more than 150,000 lb. per sq.in., and elongation ranging from 15 per cent to 25 per cent, are available. Because of the relatively high elongation the material can be rolled, drawn, bent, or formed and the resultant structures require no heat-treatment or other stress-relieving or annealing process. Its high fatigue strength, approximately 50 per cent of the ultimate tensile strength, is particularly important in aircraft structures subject to intermittent and vibratory stresses.

The stainless steels available commercially are too numerous to classify. That most commonly used in aircraft structure, and to which the remainder of this discussion will be confined, is the austenitic alloy containing about 18 per cent chromium and 8 per cent nickel with relatively low carbon, commonly known as 18-8. It can be work hardened to ultimate tensile strength of more than 200,000 lb. per sq.in. However, the tensile strengths commercially available at present are full hard, 185,000 lb. per sq.in.; half hard, 150,000 lb. per sq.in.; quarter hard, 125,000 lb. per sq.in.; and annealed, 80,000 lb. per sq.in. They are non-magnetic in the quenched state and are tough ductile.

The full hard 185,000 grade is used most frequently. Unless specifically indicated otherwise, all examples and illustrations given in this article are structures fabricated of this grade material.

In designing for tension loads the advantages of the material are apparent. The high allowable tensile strength can be utilized. However, in designing for compression loads the action of the material under compression must be analyzed.

Column Design—In Fig. 1 the average

spread of values for the physical properties is given. Stainless steel in the purely elastic range of deformation has, like ordinary carbon steel, a modulus of elasticity ranging between 28,000,000 and 29,000,000. The stress range for purely elastic behavior is, however, considerably lower, as shown in Fig. 2 which is a typical tension stress-strain diagram.

A curve of the variation of the modulus of elasticity with stress is shown in Fig. 3. It was plotted from a representative stress-strain curve similar to that shown in Fig. 2. The specimen had an ultimate tensile strength of 188,000 lb. per sq.in. The proportional limit occurs at a stress of 40,000 lb. per sq.in., the modulus up to this point being a tangent modulus. Above this stress the secant modulus is used. The secant modulus is graphically represented in Fig. 2 as the slope of the line from zero stress to any point on the stress-strain curve. The secant modulus curve is obtained by taking the stress at any point and dividing it by the unit strain for the point.

It should be noted here that the point at which the stress-strain curve departs from the straight line, known as the limit of proportionality, is variable. It is partially controlled by the technique of rolling the strip. Thus, one steel company supplies stainless steel strip with a proportional limit of over 100,000 lb. per sq.in., while stainless purchased to the same specification from another company has a proportional limit of only 40,000 to 45,000 lb. per sq.in. Material with the upper range of proportional limits is preferred.

It is customary when purchasing stainless steel for aircraft, to pull sample tensile specimens from all rolls of stock received and classify the material in the stock room with regard to its elastic properties. In fabricating any structure the work order sheet which accompanies it contains a record of the material stock roll numbers. Therefore it is possible at any time to determine the exact properties of any finished article.

Allowable Stresses

Curve 1 of Fig. 4 is a conventional Euler-Johnson curve for material having a yield point of 150,000 lb. per sq.in. and a constant modulus of 29,000,000, with a coefficient of fixity of 2. Curve 2 of Fig. 4 shows an allowable stress curve with variable secant moduli, as taken from Fig. 3. Regardless of coefficient of fixity, the point where the curve changes from Euler to Johnson range occurs at 68,000 lb. per sq.in. Examination of the two curves shows very little difference in allowable unit stress since the yield point is the dominant factor in the Johnson range. It should be remembered that the Euler-Johnson curve is an arbitrary design curve. The test values for most materials approach the yield point as a cut off at values of L/ρ substantially above those shown. Reference (h). In the Euler range the allowable stress is proportional to the value of the modulus. Therefore, in the design of long columns it is only necessary that the modulus remain high up to the point of tangency with the Johnson curve.

As has been previously noted, it is commercially feasible to secure stainless steel with a proportional limit as high as 100,000 lb. per sq.in. Therefore, the range of modulus variation as shown in Fig. 3 need not be considered in long column design.

The values in the Johnson range given by the curves in Fig. 4 should be used with discretion. In structures made of relatively light gages the possibility of a third type of failure, local elastic instability, or local buckling, must be considered. To avoid this type of failure it is necessary in design to limit the flat pitch, that is, the distance across any unsupported flat surface divided by the thickness of the material.

A range of typical column curves of a section which might be subject to failure through elastic instability failures is shown in Fig. 5. Curve 1 in this figure is a reproduction of the usual Euler-Johnson curve shown in Fig. 4. Curves 2, 3, 4 and 5 might be considered as representative of a section such as sketched on the figure made by sheets of various thickness. All of these curves are tangent to the Euler-Johnson curve at some stress, and show very slight increases in allowable stresses in the range of L/ρ

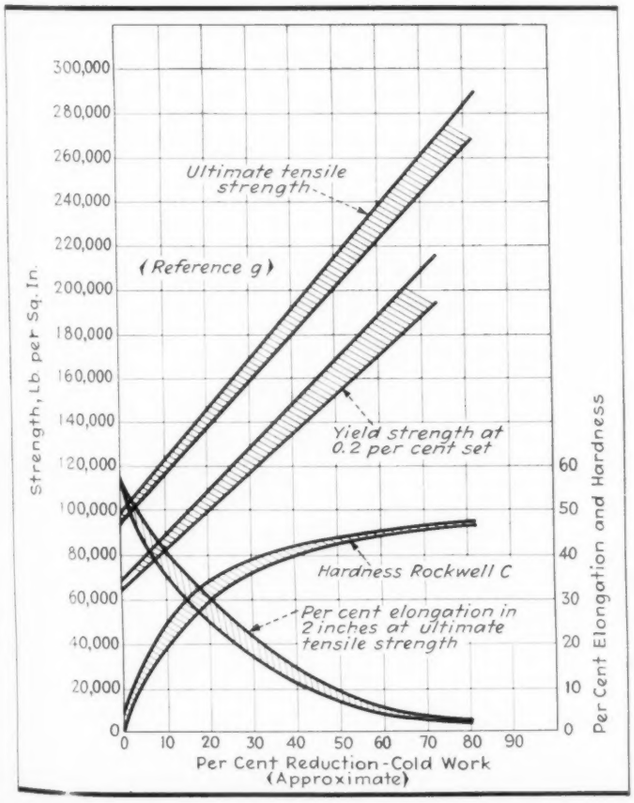

Strength, Lb. per Sq. In.
Per Cent Elongation and Hardness
Ultimate tensile strength
(Reference g)
Yield strength at 0.2 per cent set
Hardness Rockwell C
Per cent elongation in 2 inches at ultimate tensile strength
Per Cent Reduction-Cold Work (Approximate)

Fig. 1 Average spread of values for properties of 18-8 stainless

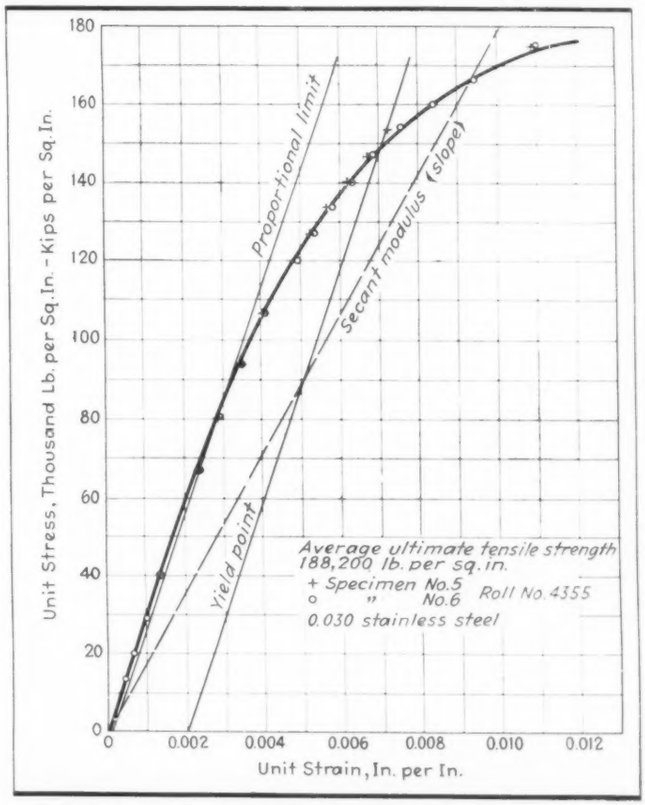

Unit Stress, Thousand Lb. per Sq. In. - Kips per Sq. In.
Proportional limit
Secant modulus (slope)
Yield point
Average ultimate tensile strength 188,200 lb. per sq. in.
+ Specimen No. 5
o " No. 6
Roll No. 4355
0.030 stainless steel
Unit Strain, In. per In.

Fig. 2—Typical tensile stress-strain diagram for 18-8 stainless

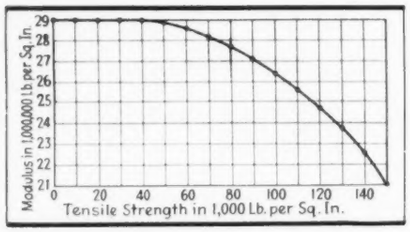


Fig. 3—Curve showing the variation of modulus with unit stress

below this point of tangency. This stress is commonly known as the crippling stress.

The conclusion to be drawn from Fig. 5 is that in the design of any column to be made of thin stainless steel sheet it is important to determine the range of L/ρ in which ratio the column is to be designed before selecting the section to be used. If in the short column range, and therefore liable to fail through direct elastic instability it will frequently be advantageous to reduce the radius of gyration, that is, the over-all dimensions of the section, in order to secure a more favorable flat pitch ratio; or, if this is undesirable, to use a beaded or rolled section.

This, it might be added, is a major difficulty in designing special sections. Because of the wide range in sections and thicknesses available for any given problem, in selecting any section for column use, inevitably the engineer will attempt to design for a stress as high in the Johnson range as possible by expanding the overall dimensions to increase ρ and decreasing the thickness to attain minimum area, hence minimum weight. However, he finds on checking for elastic instability that test results and theory indicate he has been too optimistic in his selection, and several attempts are required until the most efficient combination of L/ρ and flat pitch ratio is reached.

For the sections in common use, a family of curves similar to those shown in Fig. 5 are usually available.

Spot Welding Design

Before proceeding further, the allowable values for the strength of the spot welds in 18-8 should be considered. These values are based on the use of spot welding equipment which can be set by the operator to control very accurately the time interval, the electrode pressure, and voltage or current through the weld. Both mechanical and electronic timing devices can be used.

The shear stress of single spot welds in stainless steel sheets of various thicknesses, as required by the U. S. Army Air Corps, is shown in Fig. 6. In the design of spot welded joints it is customary, as in rivet practice, to avoid stressing the spot weld in tension. However, like a rivet, a spot weld is capable of developing some strength in tension. The variation in this figure depends, of course, on concentricity or eccentricity of the load. The button type of failure usually found in aircraft welds, the weld failing by tearing away from the parent metal around it, leaving the weld as a button, is a function of the shear strength of the material, diameter of the weld and thickness of sheet. In Fig. 7 are shown a few designs of good and poor welding.

Miscellaneous Welding Notes

Following are some precautions to observe in designing spot welded joints:

(a) The number of spot welds at any

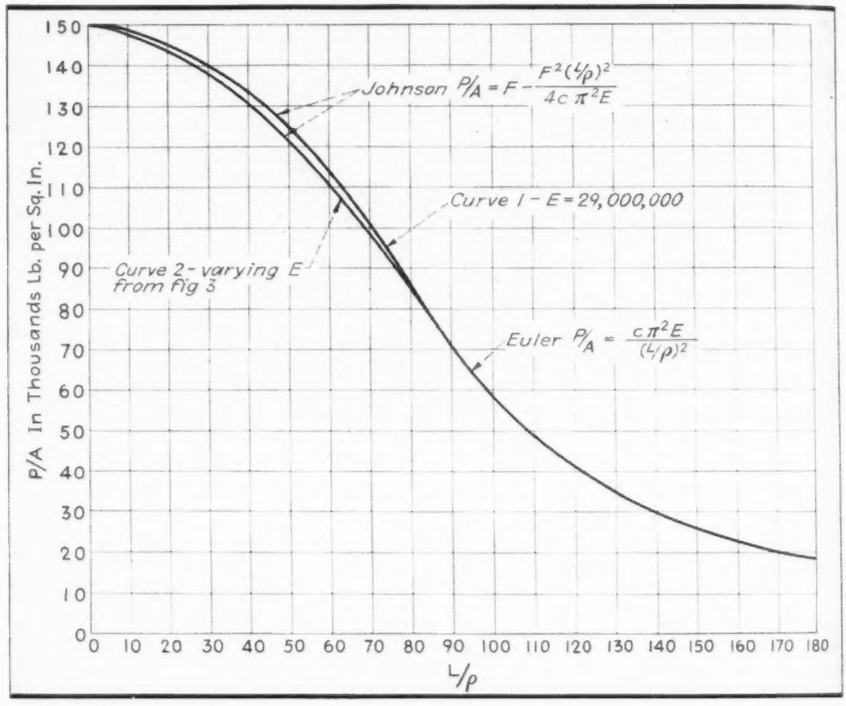


Fig. 4—Conventional Euler-Johnson curve and, Curve 2, an allowable stress curve with variable secant moduli

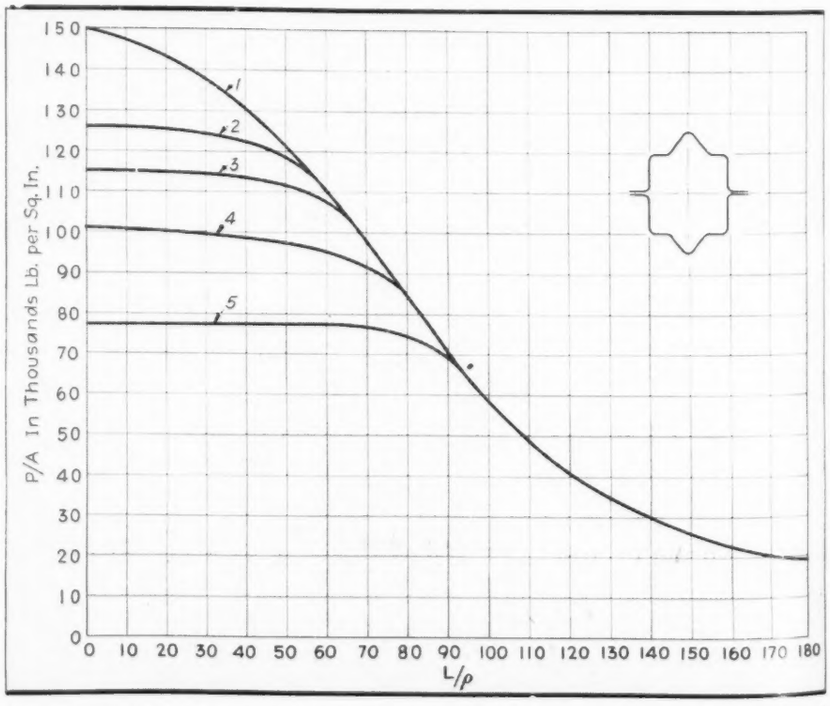


Fig. 5—Typical column curves for a section which might be subject to failure through elastic instability

joint should be increased by 50 per cent of the number required as calculated from the design load and minimum strength per spot, to allow for variations in welding.

(b) When a spot welded joint is subject to reversals of stresses or extensive variation in stresses, the number of spots should be further increased by an additional 100 per cent, thereby giving a total factor of 1½x2, or 300 per cent, based on design load.

(c) Spot welds should be spaced two weld diameters apart. In the light gages this spacing can be diminished considerably without serious proximity effect.

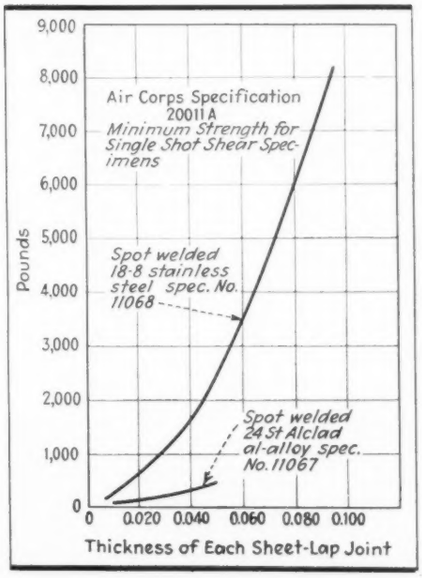
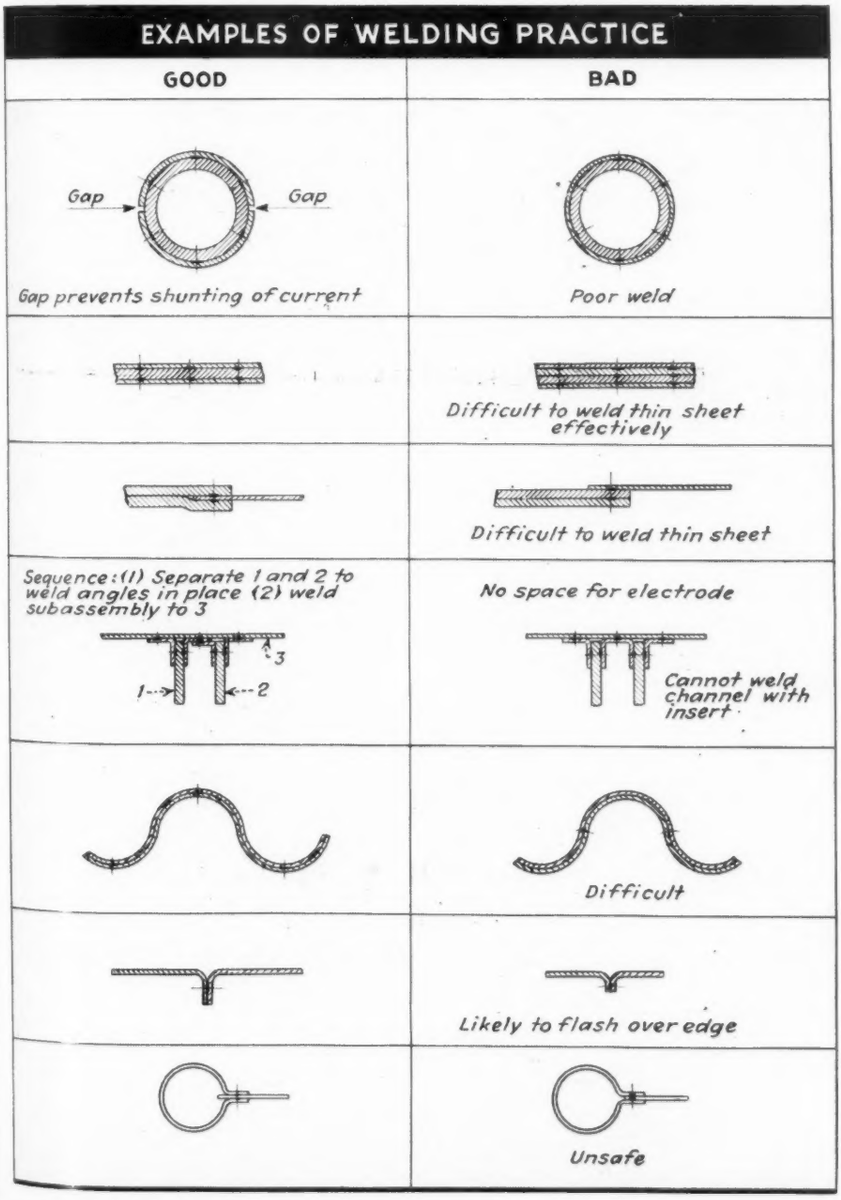


Fig. 6—Air Corps Specification 20011A for the minimum strength of single spot welds in shear

Fig. 7—Examples of good and poor designs for spot welding



For convenience the gages are designated as light (0.006–0.018 in.), medium (0.020–0.040 in.) and heavy (0.045–0.065 in. or greater). When the direction of the applied load is such as to cause the weld to tear away at the end of the sheet, the edge distance should be 1½ weld diameters. To obtain full strength the weld should be at least one-half diameter from the edge.

(d) When welding together two sheets of different thickness the shear strength of the thinner of the two should be used for design. Where additional shear strength is required for welds, the electrode diameter may be increased over

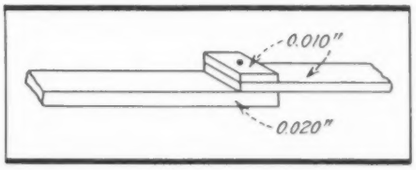


Fig. 8—Method of reinforcing a weld by means of a strip placed over the thinner of the two sheets

that recommended for the particular gage, since the strength of the weld is proportional to its diameter. Where sheets of different thickness are to be welded together the shear strength may be increased by welding a strip of sheet over the thinner of the two to make the thickness of the combination equal to that of the thicker. The joints shown in Fig. 8 will develop the full shear strength of the 0.020 in. sheet.

(e) Annealed stainless gives weld strengths 40 per cent lower than those obtained in full hard sheet. Other grades do not differ appreciably.

(The concluding part of this article will appear next month.)

REFERENCES

(a) Army-Navy Specifications ANC-5. "Strength of Aircraft Elements"

(b) N.A.C.A. Technical Report No. 479. "Thin Walled Tubes in Torsion"

(c) "Stainless Steel in Aircraft," W. L. Sutton, *Aviation*, June and July 1935

(d) "Stainless Steel Construction," W. L. Sutton, *Aero Digest*, July 1935

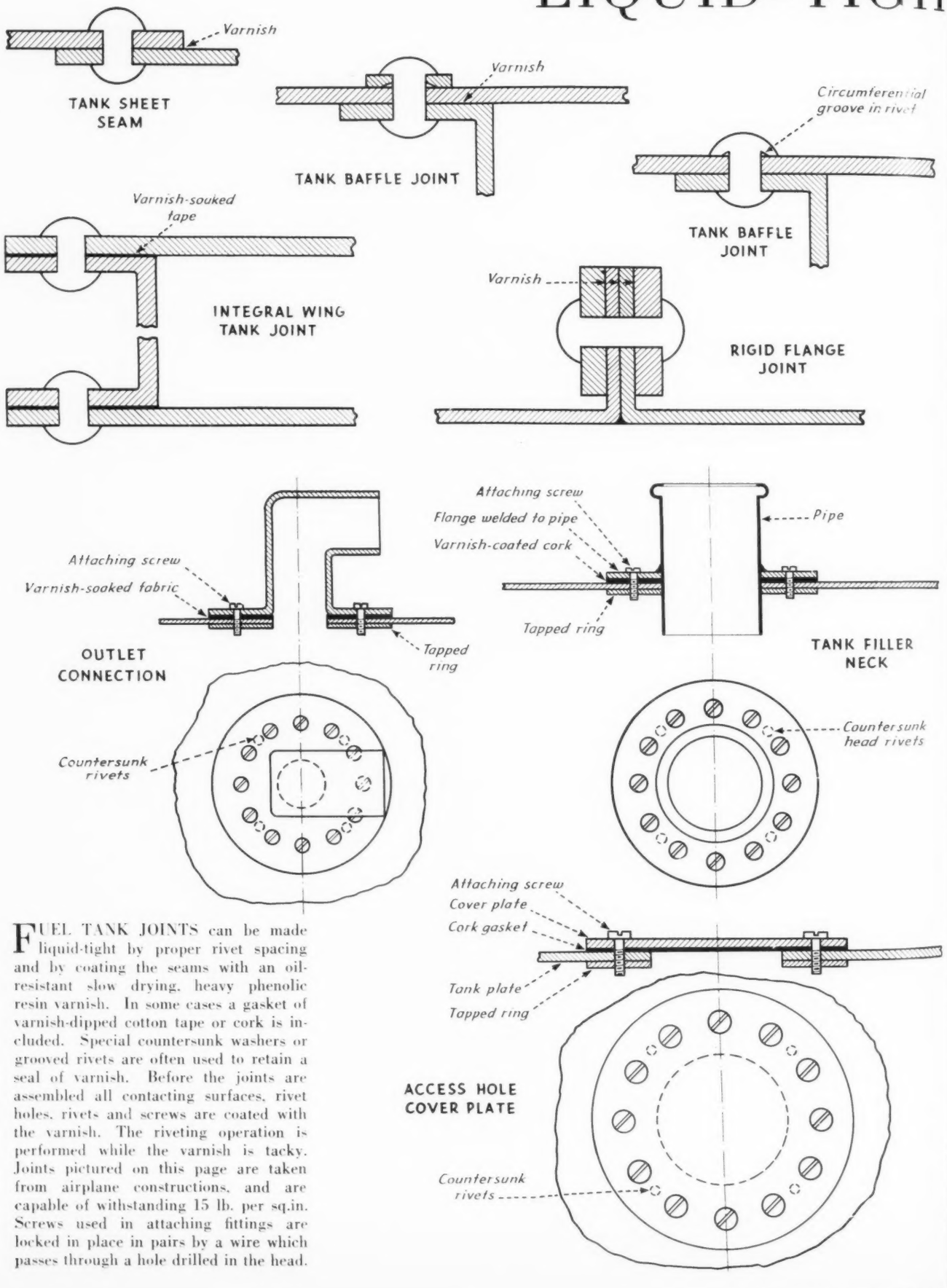
(e) "Stainless Steel for Aircraft Design and Fabrication," W. L. Sutton, *Metal Progress*, June 1936

(f) "Stainless Steel for Aircraft," Carl C. de Ganahl and W. L. Sutton, Institute of Aeronautical Sciences, 1938 West Coast Meeting

(g) "Stainless Steel in Aircraft," Herbert V. Thaden, *Journal of the Aeronautical Sciences*, September 1938

(h) "Theory of Elastic Stability," S. Timoshenko

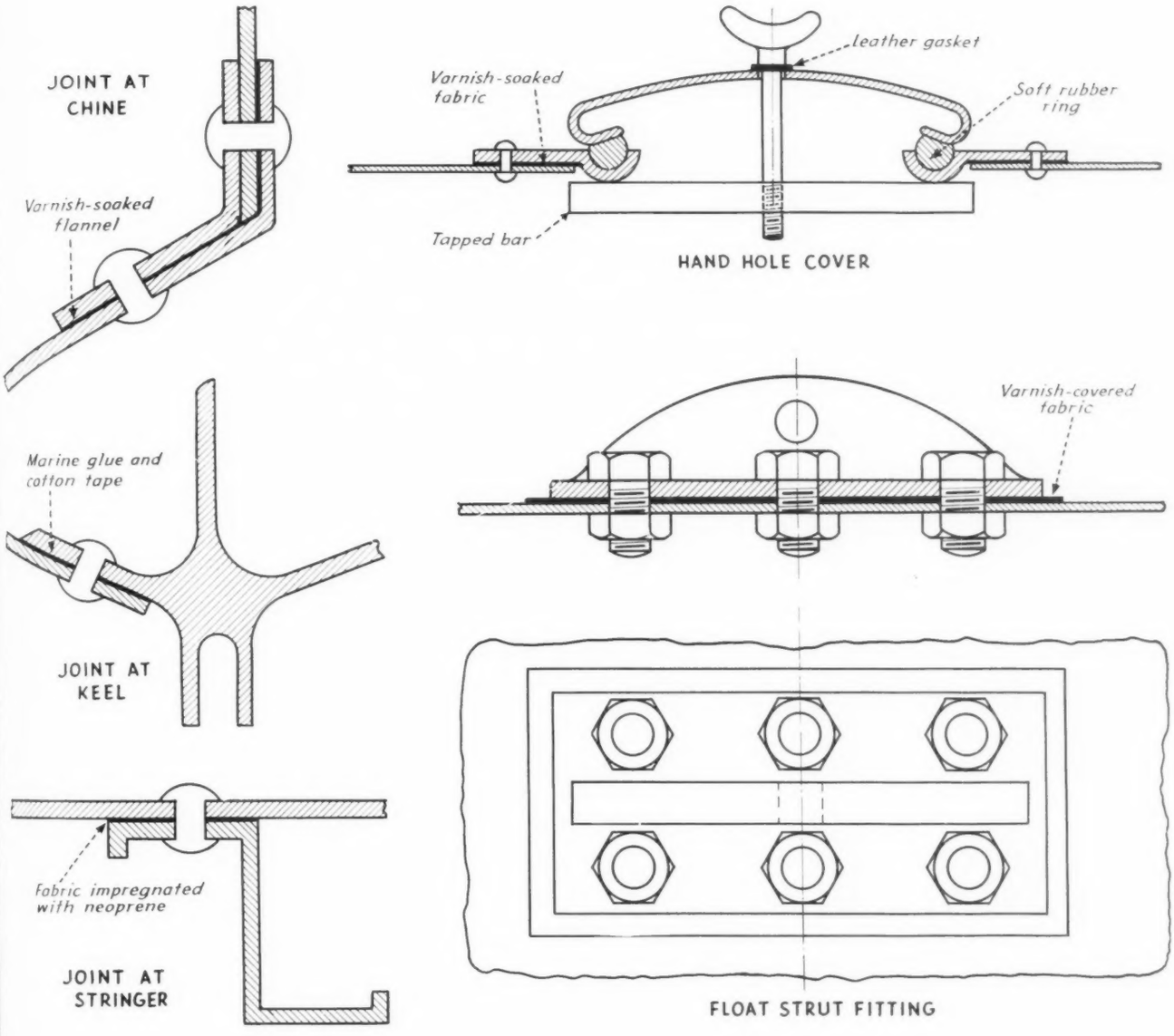
LIQUID-TIGHT RIV



FUEL TANK JOINTS can be made liquid-tight by proper rivet spacing and by coating the seams with an oil-resistant slow drying, heavy phenolic resin varnish. In some cases a gasket of varnish-dipped cotton tape or cork is included. Special countersunk washers or grooved rivets are often used to retain a seal of varnish. Before the joints are assembled all contacting surfaces, rivet holes, rivets and screws are coated with the varnish. The riveting operation is performed while the varnish is tacky. Joints pictured on this page are taken from airplane constructions, and are capable of withstanding 15 lb. per sq.in. Screws used in attaching fittings are locked in place in pairs by a wire which passes through a hole drilled in the head.

RIVETED JOINTS

FRED M. MORRIS



LIQUID-TIGHT RIVET SPACING

For 17ST Aluminum Alloy Round Head Rivets and Plate

SMALLEST PLATE THICKNESS	RIVET DIAMETER	EDGE DISTANCE	PITCH SINGLE ROW	PITCH DOUBLE ROW	DISTANCE BETWEEN RIVET ROWS
0.023 in.	3/32 in.	1/4 in.	3/8 in.	13/32 in.	5/16 in.
0.029	3/32	1/4	3/8	13/32	5/16
0.036	1/8	5/16	1/2	9/16	13/32
0.045	5/32	3/8	5/8	23/32	1/2
0.051	5/32	3/8	5/8	23/32	1/2
0.064	3/16	3/8	3/4	1 3/32	1/2
0.081	1/4	15/32	1	1 17/32	5/8
0.100	5/16	19/32	1 1/4	1 15/16	25/32
0.125	3/8	11/16	1 1/2	2 5/16	15/16
0.157	1/2	27/32	2	3 3/32	1 1/4
0.250	5/8	1	2 1/2	3 7/8	1 9/16

WATER-TIGHT JOINTS and fittings used in airplane hull and float construction are sealed in the same manner as fuel tank joints. Neoprene-impregnated tape, wet with kerosene to make it sticky, is used for straight seams. Domet flannel or cotton tape soaked in a water-resistant soy bean oil varnish or in marine glue is used at corners and complicated joints. All contacting surfaces, rivet holes, rivets, and screws in these joints are varnished before the joints are assembled. Excess varnish is removed with a solvent before it has dried to save time in the painting operation. Seams made in this manner are capable of withstanding 15 lb. per sq.in. Practically all metallic parts of these joints are constructed of aluminum alloy for lightness.

Question and Comment

Backing for a Horseless Carriage

H. I. PHILLIPS

[*Editor's Note*—Because this article, written by H. I. Phillips in the New York *Sun* and the Associated Newspapers, Incorporated, presents an extremely interesting and adequate coverage of its subject, we reprint it here with permission of the author.]

THEN

A man demonstrates a horseless carriage and asks financial backing. He says his name is Henry Ford.

Nobody knows him.

He says he needs about $2,800.

He gets it.

The business starts.

It prospers.

TODAY

A man demonstrates a horseless carriage and asks financial backing. He says his name is Ford.

Nobody even asks his first name after he mentions $2,800.

He goes to some wealthy men who tell him "this is no time to take chances."

He goes to a banker. The banker says a horseless carriage might go all right, but the bank is putting all its money into government bonds.

He goes to a close friend who expresses the belief a horseless carriage might have a future, but that on account of the economic setup, the unbalanced budget, the inflation scare, etc., it is no time to launch a new project.

He goes to another close friend, who is quite delighted with the horseless buggy but who "isn't putting any money into anything now on account of the European situation."

He goes to a politican with financial connections. The politician says a horseless carriage looks okay on paper and might be profitable, but that to replace the horse and buggy would be to throw blacksmiths, hack drivers, feed store workers, harness makers, etc., out of work and bring on a revolution.

He finally locates a couple of capitalists who have imagination enough to see a future for the automobile, but he drives them out by predicting that "they will make millions."

He decides to try Wall Street.

The SEC demands a demonstration. The car works perfectly, but the commission cautions Mr. Ford against undue optimism and overstatement. It holds up everything while it makes a six months' inquiry to see if his right name is Henry Ford.

A broker agrees to float stock.

The flotation is rendered difficult by SEC rules that lines in the advertisements such as "may ultimately become as popular as the horse" and "destined in time to come into general usage on city streets" be deleted in the interest of honesty.

Ford quits Wall Street, finally gets $2,800 from a group of friends—Heaven knows how—and starts a small shop.

Labor delegates warn him that for every man he hires to make an auto he must hire at least one livery stable worker.

There are a series of strikes. They are referred to the NLRB.

The NLRB investigates for a year and a half and files a report charging that a horseless carriage industry is unfair to whip makers, and that Mr. Ford means to create industrial slavery.

There are frenzied speeches in the Senate and House in denunciation of the new invention by orators who speak as "a friend of that noble animal, the horse."

The President names a Commission to Inquire Into the Aspects of the Horseless Carriage With a View to Possible Effects on the Economic and Social System.

Mr. Ford goes into bankruptcy.

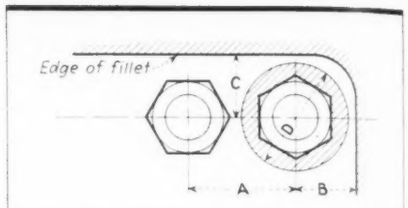
He scraps the auto and decides to raise Belgian hares at home through six simple lessons.

Motor Connection Diagrams

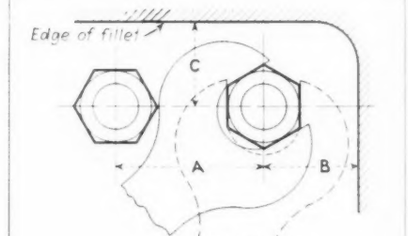
To the Editor:

We regret very much that an error appears in the Reference Book Sheet of connection diagrams, *Product Engineering*, May 1939, page 224. This error is entirely ours. Referring to the last line in the table of connections in the upper right-hand corner of the page for Two Winding —Three Speed, Three Phase, Constant Horsepower ASA C-6, 3.725 1938. L_1 should connect to T_{10}, L_2 to T_{11}, and T_{12} and L_3 to T_{13}. —W. S. RIGBY

Wagner Electric Corporation



Bolt Size	Socket Wrench				Open End Wrench		
	A	B	C	D	A	B	C
1/4"	3/4"	1/2"	1/2"	3/4"	1"	7/8"	5/8"
5/16"	1 1/8"	3/4"	3/4"	1 1/8"	1 3/8"	1 1/8"	3/4"
1/2"	1 5/8"	7/8"	7/8"	1 3/8"	1 3/4"	1 3/8"	7/8"
5/8"	1 5/8"	1"	1"	1 5/8"	2 1/8"	1 1/2"	1 1/8"
3/4"	1 7/8"	1 1/8"	1 1/8"	1 7/8"	2 5/8"	1 5/8"	1 1/4"
7/8"	2 1/8"	1 1/4"	1 1/4"	2 1/8"	3"	1 7/8"	1 5/8"
1"	2 3/8"	1 3/8"	1 3/8"	2 3/8"	3 1/4"	2 1/8"	1 7/8"
1 1/8"	2 5/8"	1 1/2"	1 1/2"	2 5/8"	3 5/8"	2 1/4"	1 7/8"
1 1/4"	2 7/8"	1 5/8"	1 5/8"	2 7/8"	3 7/8"	2 1/2"	2"
1 3/8"	3 1/8"	1 3/4"	1 3/4"	3"	4 3/8"	2 3/4"	2 1/4"
1 1/2"	3 3/8"	1 7/8"	1 7/8"	3 3/8"	4 7/8"	2 7/8"	2 1/2"



Wrench Clearances

To the Editor:

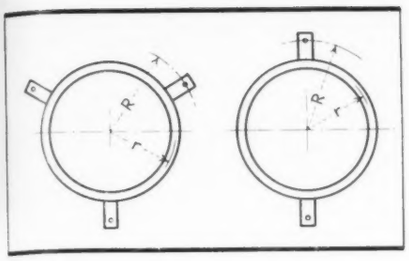
The accompanying diagrams and table give recommended minimum corner clearance and bolt center dimensions for socket wrenches, and recommended minimum corner clearance and bolt center dimensions for open end wrenches. These dimensions have been tried and found accurate. —L. R. RUSSELL

Milwaukee, Wis.

Ring Stresses

To the Editor:

The problem of computing the stresses in rings similar to the ones shown here has long bothered me. A total load of P is uniformly distributed around the ring. This uniformly distributed load may be assumed to pass through the center of gravity of the ring parallel to the ring's axis. The ring is supported by either two or three equally spaced lugs at points



equidistant from its center. Have any of the readers of *Product Engineering* a general solution for this problem?

—R. L. Jensen
LeRoy, N. Y.

Is Industrial Design a Profession?

To the Editor:

I am writing to ask whether, in your opinion, Industrial Design should be classified as a profession—in the same way that we rank an artist, engineer, doctor or lawyer. We feel that it is a "profession," but would like to have an opinion from an impartial source.

—Raymond Loewy
New York, N. Y.

Strength of Thin Pipes

To the Editor:

The strength of thin pipes under internal pressure is generally calculated from the formula $S = \frac{Pd}{2t}$ in which S is fiber stress in lb. per sq.in., d is internal diameter in in., t is wall thickness in in. The formula may be applied for estimating the bursting pressure affecting the pipe wall rupture. In that case S corresponds to the ultimate strength of pipe material.

A question may arise whether the tangential ultimate strength of material in the pipe is equal to the ultimate tensile strength of material used for manufacturing the pipe or not. I believe that the ultimate tangential strength of material in the pipe will have considerable deviations, depending on the method of manufacturing the pipes, seamless pipes, welded pipes, etc. I remember certain regulations issued for testing boiler plates, prescribing strength of material tested across the fibres 20 to 25 per cent lower than strength along the fibres. The fundamental formula relates evidently the strength across the fibres. It would be interesting to know what relationship exists between tangential and ultimate tensile strength of material in the pipes. For that purpose, sample test pieces should be cut from pipes, larger sizes are preferable, in cross and longitudinal direction. The results of such tests might throw light on 1-in. and 2-in. welded pipe tests performed by the Bureau of Standards (see *Journal of Research*, vol. 4, No. 4, April, 1930). The tests of 2-in. pipes showed that the tangential ultimate strength of material in the pipes is 1 to 9 per cent higher than the ultimate tensile strength of material used for manufacturing. Actually, a certain weakening of the pipe wall by welding process results in an inverse relationship of the above strengths.

—Victor Tatarinoff
Pilsen, Czechoslovakia

Nomogram for Length of Rolled Material

To the Editor:

Several years ago you published a small nomogram for the length of material in a roll, but it was of limited application because only four separate inside diameters were assumed. In the chart given here the inside diameter is one of the variables, ranging from 2 to 30 in. Outside diameter is included up to 34 in., and thickness of material ranges from 0.0225 to 1 in.

The nomogram for the length of material in a roll is the graphical evaluation of the well known equation.

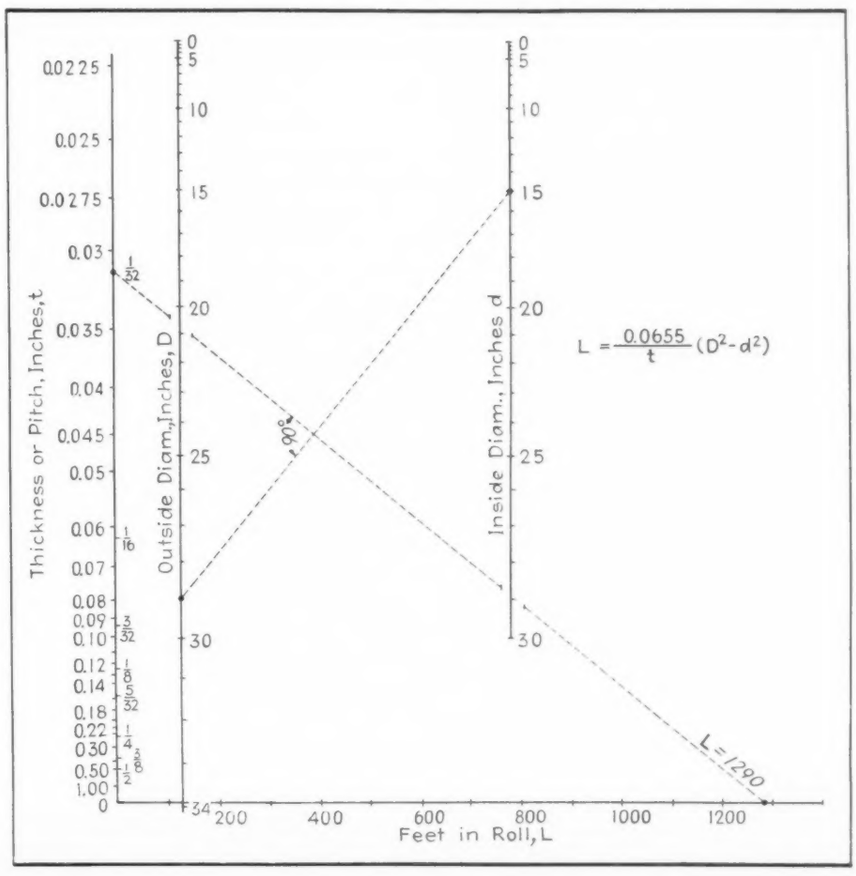
$$L = \frac{0.0655}{t} [D^2 - d^2]$$

in which L is the length of roll in feet, d and D are the inside and outside diameters of the roll, respectively, and t the thickness of the material, all in in. The formula assumes the roll to be not spiral, but made up of concentric circles, which generally involves a negligible error.

To use the chart most conveniently, draw a pair of lines crossed at 90 deg. on tracing cloth, waxed paper, or celluloid, and shift this templet over the chart until three of the legs pass through the given values on the several scales. Then the fourth leg will cut the remaining scale at the required value. In the position of the templet shown in the chart, the ½ in. material is wound on a mandrel 15 in. in diameter to an outside diameter of 29 in., and its length is found to be 1290 ft. by the fourth leg on the bottom scale. One of the lines of the templet must always cut the two parallel scales D and d, and the other line the angled scales t and L. For clarity, small circles are shown on the scales at the significant intersections of the computing secants, and they are interrupted where the are to be no intersections.

Since the material will not generally be wound tightly on itself, t includes a clearance, which may have to be determined experimentally.

This somewhat unusual form of nomogram, embracing two angled and two parallel scales, graphically solves any equation including a function of four variables, in which the sum (or difference)



of two of them equals the product of the other two; and has the merit of requiring only a single setting of the templet. Of course, the transparent templet is not necessary, as one line may be drawn across the known scales, and the other from the point on the third scale, perpendicular to the first line, by using the corner of a sheet of paper as a right angle.

—Carl P. Nachod
Nachod & U. S. Signal Company

That Milkmaid Problem

To the Editor:

I believe your milkmaid problem on page 210 of the May number could have been made more interesting if the question had been asked how to obtain 13 gal. in the 14 gal. container and 1 gal. in the 5 gal. container.

Furthermore, of all the 60 combinations in which 14 gal. may be divided among the three given containers, only 28 of these combinations appear possible to obtain.

—David Lindquist
Chief Engineer
Otis Elevator Company

More Canny Measurement

To the Editor:

In the June number of *Product Engineering*, page 257, is published the solution to the problem of isolating 7 gal. from 14 gal. of milk contained in a 14 gal. container, by using as auxiliary measures only a 9-gal. and a 5-gal. can.

This is a special case of the very interesting general problem, as follows:

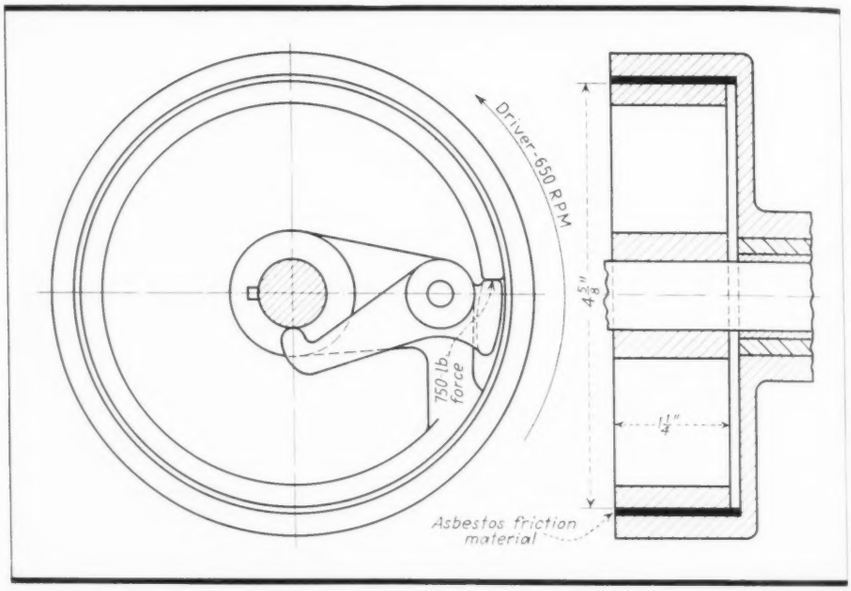
Let the capacities of three containers, A, B, and C be respectively a, b, and c gal. where a is even and $a = b + c$; and let m be the greatest common divisor of a, b, and c, so that $a = ma'$, $b = mb'$, $c = mc'$. Then $a' - 2$ moves are necessary and sufficient to isolate $\frac{a}{2}$ gal. provided a' is even; if a' is odd, it is impossible to isolate $\frac{a}{2}$ gal.

One consequence of the above theorem is somewhat surprising. The number of moves is wholly independent of the values of b and c, but depends only upon a and m. Thus, in the problem you publish, twelve moves are required for $b = 11$ and $c = 3$, or for $b = 13$ and $c = 1$. Similarly, 38 moves are required to isolate 20 gal. from a 40-gal. container if $b = 27$ and $c = 13$, or if $b = 37$ and $c = 3$, or for any other choice of b and c so long as there exists no common factor of a, b, and c. But if $b = 25$ and $c = 15$, then $a' = 8$, $b' = 5$, and $c' = 3$, in which case only six moves are required to isolate 20 gal.

This seems to be an instance, trivial though it may be, of the danger of using "cut-and-try" methods of solving certain problems without recourse to formal mathematical analysis. Although I am not a professional engineer I have had considerable experience in engineering practice and in engineering environments, and have found too often among engineers of the self-styled "practical" sort the disposition to depend upon "cut-and-try" methods in cases where formal mathematical analysis might not only save time, but would avoid results which are either insufficient or inaccurate.

—L. S. Johnston
Professor of Mathematics
University of Detroit

Expansion Ring Clutch



To the Editor:

The essential dimensions of an expansion ring clutch are given on the accompanying drawing. The lining is of asbestos friction material with a coefficient of friction of 0.55, and is $\frac{1}{8}$ in. thick. The driver rotates at 650 r.p.m. A force of 570 lb. is exerted against the free end of the expansion ring. This force is exclusive of the self-energizing effect.

I would like the answers to two questions concerning this clutch. The first one is, what is the radial pressure between the expansion ring and the driver caused by the 570 lb. force. Secondly, what would be the maximum safe horsepower to transmit through a clutch of this design and size with these conditions.

—William F. Cruise
Racine, Wis.

Can You Work This One?

H. E. SMITH

Solution to July problem—

Ferdinand the Bull

Ferdinand, the bull, was left standing at the end of his 100-ft. tether, the other end of which was tied to one corner of a 25-ft. square barn in the middle of a large grassy plot. He, in all his dumb magnificence, was vainly trying to figure out the total area of grass upon which he could graze. Unless he knew the value of π to about ten decimal places, the best answers he could get would range between 30,290 and 30,300 sq. ft. In order to get the exact answer, use of the longer π value would be required.

This month's problem—

Keeping the Guards Away

A servant was ordered to deliver to His Royal Highness, the King, one apple from the most highly prized tree. This tree was closely guarded by three men. In order to get the one apple to fill his orders, the servant was told to pick several apples, and then, as he met each successive guard, to give each man one-half of the number of apples he carried, plus one-half an apple, without cutting, slicing, or breaking. The servant, being a clever man, was easily able to figure out the number of apples required. What was it?

News

Glass Produced by New Process Has Properties of Fused Quartz

Coefficient of expansion of new glass is one-quarter that of previous low-expansion glass, one-tenth that of regular glass

OF GREAT IMPORTANCE in that it will offer at an economical price a material similar to fused quartz, a new low-expansion glass has recently been developed in the Research Laboratories of Corning Glass Works. Whereas fused quartz is not a mass-production commodity, indications are that this new glass product can be manufactured by volume production methods and at resultant low costs.

A remarkable point about the new process is that articles made by it shrink to about two-thirds their original volume, yet show no distortion of form. This means a linear shrinkage of 13 per cent. Technical description of the most important steps in the new Corning glass-making methods is as follows: The starting object, such as a disk, glass, beaker or tube, is produced from certain special types of borosilicate glasses which are somewhat unstable. By means of a heat-treatment these glasses are separated into two phases, one being high in silica and highly stable, the other containing substantially no silica and being very soluble in a common acid. This second phase is then extracted by leaching in an acid bath for some time, which leaves a skeleton-like structure of high-silica glass, with only 64 per cent of the original body of the glass remaining.

At this stage the surface feels rough to the touch, but does not feel porous. Actually it is filled with sub-microscopic capillaries or air spaces. The porous glass body is then fired at a vitrifying temperature; this condenses the structure into a clear, solid mass. It is during this heating that the shrinkage occurs.

In its completed stage the glass is practically 96 per cent pure silica, and can be dipped into a vat of ice water after heating to a bright cherry red color with no injury whatsoever. The quartz-like material can be used up to 1,000 deg. C. for considerable periods. Its softening point is at 1,442 deg. C. It has a coefficient of linear expansion of 7.8 to 8×10^{-7}, as compared with 32 to 33×10^{-7} for previous low expansion glass, and 5.5 to 5.8×10^{-7} for fused quartz.

The new process marks a climax of 16 years' research in heat-resistant glassware. Although miniature pilot plants have been operating for several months, Corning engineers estimate that at least two years will be required to put the process on a mass-production basis.

New Standard Clarifies Cutting Tool Terms

A CONFUSING SITUATION in which a tool may be called a left-hand tool in one company but may be known as a right-hand tool by another, was clarified by a new standard on single-point cutting tool terminology approved recently by the American Standards Association. The standard is divided into six sections: tool elements, types of tools, tool angles, working angles, general tools, and symbols.

The need for agreement on a standard vocabulary has long been recognized by the A.S.A. The final proposal, approved by the A.S.A. Committee on Small Tools and Machine Tool Elements, was recommended by the Society of Automotive Engineers, the National Machine Tool Builders' Association, and the American Society of Mechanical Engineers. General adoption of this standard, listed as B5.13-1939, will simplify transactions and avoid confusion which may prove costly.

Automobile Engineers Seek New Plastics

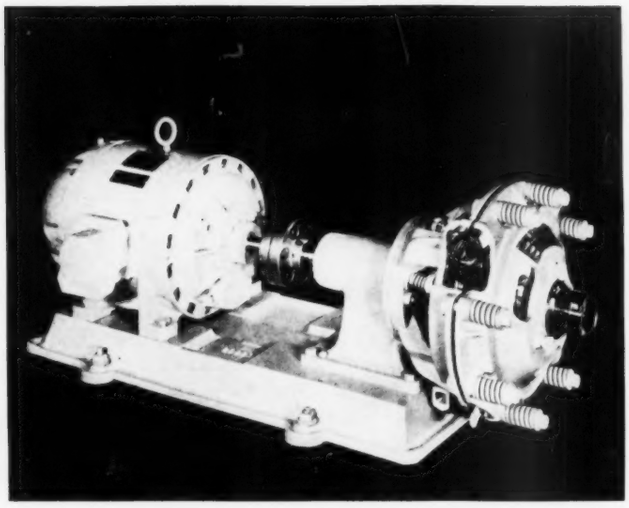
MUCH DEVELOPMENT WORK is needed before plastics will be suitable for general use in automobile body construction, according to recent statements made by leading automobile manufacturers. Before they can be used as raw materials for cars of the future, plastics must be given the strength and rigidity of alloy steel, the ease of forming and shaping of potter's clay, the toughness of sugar maple and the high precision surface finish of tool steel, said Gordon Saunders, staff officer of Chrysler Corporation.

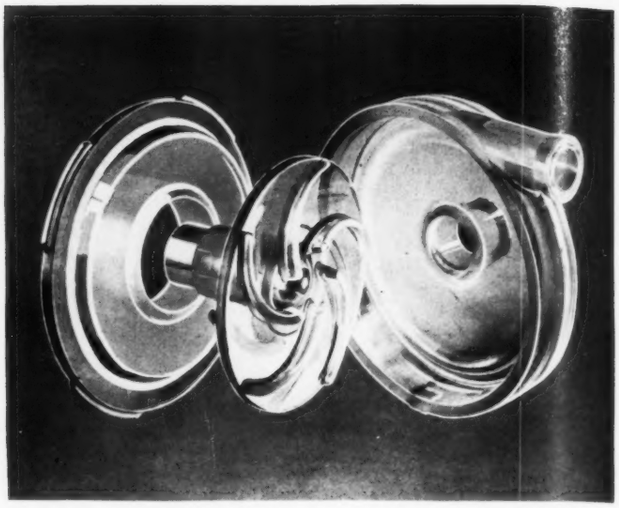
Suitable chemical dyes are needed to match painted metal bodies, stated Dr. J. L. Laird of the Ford Motor Company, in explaining the reasons why plastics are not used now in engine hoods and doors. One of the greatest drawbacks is the large production time per unit, tying up expensive equipment. Also, if plastics are to be used for body parts, some provision must be made for repairing damages.

The principle application of plastics in automobiles at the present is for interiors. Automotive engineers, who now specify plastics for moldings, knobs, instrument panels, steering wheels, are considering the introduction of interior color by using plastics in the ceiling in place of fabric.

Research engineers, only temporarily set back by the difficulties now encountered, are seriously studying plastics

Half the weight, horsepower for horsepower, of ordinary motors, the high-power motor in this router operates at high frequency. These new constant speed machines, developed by the Sawyer Electrical Manufacturing Company, have no gears, commutators, or brushes. Used by Douglas Aircraft Company, the high frequency router is said to have increased routing speed from 4 ft. up to 12 ft. per min., on aluminum parts.





Chemical-resistant glass is the only material with which corrosive liquids come in contact in this centrifugal pump —a significant example of the application of glass for mechanical parts. Its glass rotor, accurately balanced, runs at high speed without appreciable vibration, and is capable of handling 6,000 gal. of liquid per hour at a head of 70 ft. Interior of the pump, which was developed by Nash Engineering Company and Corning Glass Works, can be watched through the clear glass while in operation. For cleaning, the pump can be taken apart and reassembled in a few minutes.

from the point of view of cutting down weight on all non-load-bearing parts. It will only be a matter of time and research, according to a prominent plastics engineer, before a material will be developed which has all the desired properties of strength, good finish, speed of production and heat-resistance. Then, and only then, automobile bodies will be successfully built with "rubber" fenders.

New Device Measures Surface Smoothness

SENSITIVE enough to indicate the differences in thickness of a fingerprint on a piece of glass, a new surface indicator is used to determine the smoothness of metal or painted surfaces. Variations of as little as one millionth of an inch are clearly indicated by this instrument, developed in the General Electric Works laboratory. By its application, the surfaces of bearings or other moving parts of motors and parts of machines that are subject to wear can be tested and their smoothness indicated.

The apparatus resembles a phonograph. The object to be tested is placed on a turntable, and a sapphire-pointed stylus or needle passes over the test material as it revolves. Small mechanical impulses, created as the hard point of the needle rides over surface irregularities, are converted into electrical impulses by an electromagnetic pickup. They are then amplified and transmitted to a recording meter where the surface characteristics are graphically indicated.

The stylus or needle is so sensitive that when it is placed on the revolving metal turntable, the invisible vibrations established by a person whistling are shown on the recording meter.

Practicability of Gas Turbines Proven

POWER OBTAINED DIRECTLY from burning fuel in a gas turbine, the dream of inventors since 1791, is now a reality, according to Dr. Adolph Meyer, Director of Brown Boveri Company, Baden, Switzerland. Originally developed to supply power for supercharging high-pressure, steam-generating Velox boilers and diesel engines, the gas turbine has been found a practical, cheap and compact source of primary power, a factor of importance far outweighing its original application as an auxiliary power source.

The gas turbine operates on the same principle as the diesel engine, but is as much different in appearance and construction as the steam turbine is from the steam engine. It produces power directly from burning oil in one compact unit and delivers it on a rotating shaft without cranks, valves, timing mechanism or expensive auxiliaries found in even the most modern of our present power plants.

No one expects, said Dr. Meyer, that gas turbines will immediately replace steam turbines or internal combustion engines as the principal source of our electrical power. At present such applications as railway locomotives, high-powered ships such as destroyers, and steel-mill blast furnaces are being studied as they afford fields wherein the compactness of the gas turbine and its ability to produce large quantities of compressed air have definite advantages over any other equipment now on the market.

Steam turbines are now being operated with steam at 1,200 lb. per sq. in. and 940 deg. F. Present gas turbines use temperatures up to 1,030 deg. F. and indications are that it will be soon possible to increase the temperature to about 1,200 deg., thereby obtaining a material improvement in efficiency.

It is too early to predict what trend the future development of the gas turbines will take, but there no longer remains any question of the practicability of these units. Gas turbine and compressor sets have operated as an auxiliary to Velox boilers since 1930. Two units

MEETINGS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—*Joint meeting with the Institution of Mechanical Engineers of Great Britain, New York City, September 4-8. C. E. Davies, secretary, 29 West 39th St., New York, N. Y.*

INSTITUTE OF THE AERONAUTICAL SCIENCES—*International Congress of the Aeronautical Sciences, New York City, September 11-17. Lester D. Gardner, Secretary, 5111 R.C.A. Bldg., Rockefeller Center, New York, N. Y.*

NATIONAL MACHINE TOOL BUILDERS ASSOCIATION—*1939 Machine Tool Show, Cleveland, Ohio, October 4-13. J. T. Fenner, director of publicity, 1525 Carnegie Ave., Cleveland, Ohio.*

PACKAGING INSTITUTE—*First annual meeting, Edgewater Beach Hotel, Chicago, October 13-14. H. L. Stratton, secretary, 342 Madison Ave., New York, N. Y.*

have each served oil refiners two years or more, and another has seen service in Naples, Italy, for over two years. There are now ten additional similar units under construction or on order, and some of these will shortly be in full operation. A 2,000-hp. locomotive only 60 ft. long is now being constructed for the Swiss Federal Railway.

An interesting application of the gas turbine, and the only one to date designed primarily for power production, is the bomb-proof emergency station for the city of Neuchatel, Switzerland. It is buried in a tunnel. One of the advantages of the gas turbine power plant is that no cooling water is required. Another, is that it can be completely inclosed in a tunnel with nothing entering except a fuel line and air supply and nothing leaving but exhaust gas and a power cable.

Other possible applications for the gas turbine are found in steel plants and chemical plants which have available as by-products large quantities of waste gas which can be turned into power. The same situation exists in many of the oil fields where excess natural gas can quickly and cheaply be converted into electrical power.

Development in these fields has led to new applications of gas turbine equipment for blast-furnace installations. In these gas turbine plants, of which three have been ordered up to now, part of the blast furnace gases are burned in the combustion chamber of the gas turbine. An amount of air representing the net output of the gas turbine plant is extracted from its blowers and delivered to the furnace as blast.

Torque Preferred For Rating Engines

PREFERENCE for the use of torque instead of horsepower as a means of rating automobile engine performance was indicated in a poll of engineers taken at a recent conference of the Aluminum Cylinder Head committee of the Aluminum Association. Pointing out that horsepower rating means little to the average car owner, one prominent engineer stated: "A properly designed engine of relatively low horsepower could out-perform a high horsepower engine under practically every condition in which an owner would drive his car."

Since not one per cent of the automobiles on the road today are ever driven under conditions which permit the engine to develop peak horsepower, engine performance rated in lb. ft. of torque at 1,000 r.p.m. would be a far more accurate measure of performance than the rated number of horsepower the engine can develop at peak horsepower speed.

Stating that some automotive power plants have actually been modified to raise the horsepower rating for advertising purposes, with a sacrifice of performance in the lower speed ranges where most use occurs, the engineers added that today's need is for a good 75-hp., high-compression, high-torque engine. Educational campaigns were suggested to acquaint the public with the real significance of torque-rating as compared with horsepower-rating.

Do You Know That—

PROBABLY THE WORLD'S FIRST form of the telephone was used by Shi Huang Ti, that ancient Chinese emperor who combined conquest with construction. His communicating system was a rudely constructed hollow brass tubing extending between guard stations placed at close intervals along the 1,500-mi. Great Wall of China. (21)

ALUMINUM-COATED ceramic granules are used for pebble dashed asphaltic roofs and shingles. The aluminum reflects the sun's rays, keeping the roof and the rooms below cooler, and adds reflected light to windows facing the roofs. (22)

INTO EVERY MODERN AUTOMOBILE goes from 40 to 60 lb. of rubber, in addition to tires and tubes. (23)

Low-Priced, Light-Weight Tractors Designed to Serve Small Farm

Designed to replace the horse in small farms, this new Ford tractor costs $585, and features the Ferguson hydraulic draft principle which keeps implements at a predetermined soil depth. Snagging of the implement tends to raise the rear wheels off the ground, preventing tractor tip-over or damage to the tools. Hydraulic controls make operation simple. The 4-cylinder L-head engine develops 23 b.hp. Cast steel parts are used liberally in the construction of this light-weight machine. With three speeds forward and one reverse, the tractor has a top speed of 6 m.p.h. Independent braking of the rubber-tired rear wheels permits the 70-in.-wheelbase tractor to turn in a 15-ft. circle.

For the small farm and for light work on larger farms, this Farmall-A tractor, recently announced by International Harvester, will sell at $515. Able to plow 2-3 times as much in a day as a team of horses at a cost per acre one-quarter as great, the tractor features Culti-Vision construction, with its engine offset to the left to permit full view of the field. Engine has 3-in. bore and 4-in. stroke, replaceable cylinder sleeves, Tocco-hardened crankshaft, overhead valves, and precision bearings; fuel consumption is one gal. per hour at full load. Farmall-A has four forward speeds, independent rear wheel braking, minimum turning radius of 9 ft., and top speed of 10 m.p.h. for road hauling.

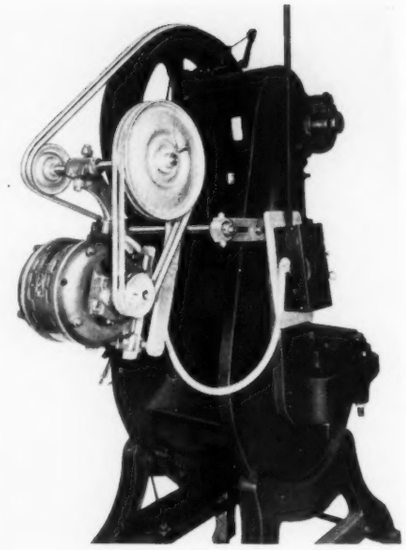
New Materials and Parts

Circuit Breaker

This new unit, designated as type MO Multi-breaker, is for use with grinders, milking machines, utility tools, and in other locations where a disconnecting switch and over current protection is needed, in the home, shop, store or farm. The unit is compact, being 6⅛ in. high, 4 in. wide and 2⅞ in. deep. Adapted to flush or surface mounting. It is factory calibrated and sealed and will always interrupt the circuit under the same overload conditions but will not open the circuit during the brief periods of high inrush current encountered in starting motors. There are no parts to replace to restore service. Available in 15-, 20- and 25-amp. sizes for 115- or 230-v. single and two pole applications where type D fusible switches have been used. Square D Co., 6060 Rivard St., Detroit, Mich.

Individual Drive

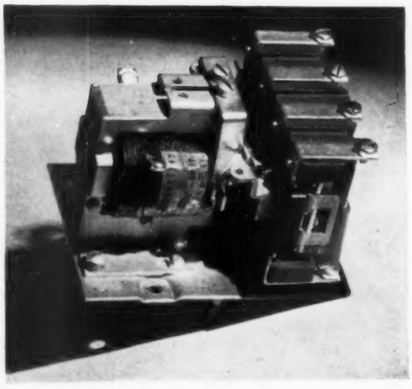
Punch presses and similar types of machine tools can be converted to individual motor drives using standard 1750-1800 r.p.m. motors with this new patented "Modern" individual punch press drive. Any desired operating speed in the usual ranges can be obtained by speed reduction through V-belt and sheave drives. The final drive runs directly on the flywheel of the press without alteration or grooving. Construction is such that



proper belt tension is easily maintained through utilization of motor weight. The complete self-contained unit can be mounted entirely within the floor lines of the machine base. Quality Hardware & Machine Corp., 5847 North Ravenswood Ave., Chicago, Ill.

Contactors

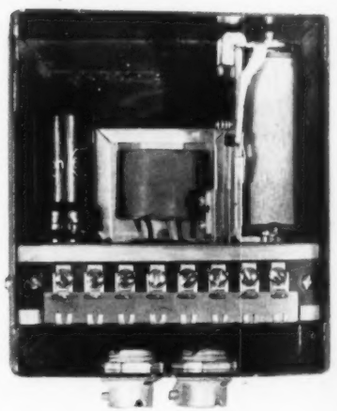
For use on machine tool control and other built-in control applications, this new line of multi-pole contactors are assembled as complete units on steel bases suitable for mounting on insulating or steel panels as part of the controller. The relays, rated at 10 amp., 500 volts, maximum, are arranged for front wiring of all connections. All terminals of the type Dn-OO contactors are designed for easy access. Available in 2 to 8 pole forms in



any combination of normally open or closed contacts which may be required for complicated control system. Westinghouse Electric & Mfg. Co., Dpt. 7-N-20, East Pittsburgh, Pa.

Electronic Switch

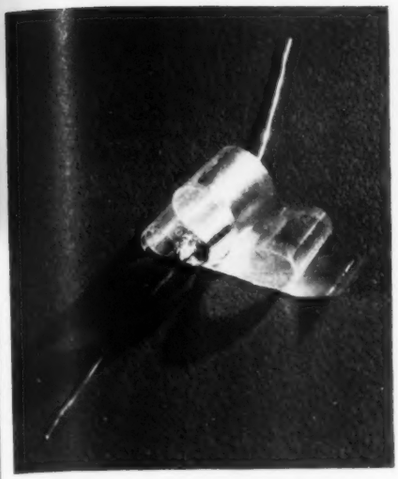
Model ES-15 electronic switch, designed to eliminate the possibility of contact arcing and welding on such equipment as thermostats, limit-switching mechanisms, contact making devices requiring very low contact pressure and limited movement, employs an electronic tube to actuate a circuit relay. Input, such as through the contact of a thermostat, is connected to the tube which requires a control current of about 1 microamp. and which permits a contact resistance to 1 megohm. The relay contacts are rated at 3 amp. on 110 v., 50- or



60-cycle non-inductive a.c. circuit. Overall dimensions are 5⅛ x 5⅝ x 3¾ in. Operation can be maintained at speeds to 900 complete cycles per min. United Cinephone Corp., 43-37 33rd St., Long Island City, N. Y.

Polystyrene Insulation

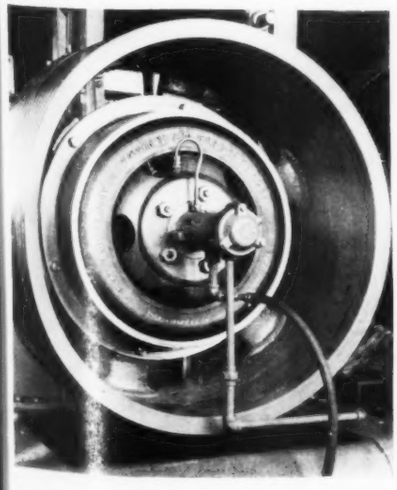
All of the advantageous properties that are found in Bakelite polystyrene molding material are incorporated in this new film which has been developed especially for uses such as wound capacitors in radio sets and other types of electrical equipment. The electrical properties of this film will remain constant even at varying temperatures. The film is water



white in appearance, but may also be had in a tinted shade of purplish black. Supplied in ribbons 1½ in. and 2½ in. wide and wound on spools to a diameter of 4 in. The standard thickness is 1 mil, but other thicknesses can be supplied. Bakelite Corp., 247 Park Ave., New York, N. Y.

Rubber Clutches

A new type of mechanical clutch, using the principle of the automobile tread which has many narrow vanes or ribs of rubber which cling to the road surface with a high degree of adhesion, is much lighter, and simpler than the conventional clutch. Because of the flexibility of pressure application, the new Airflex clutch provides uniform pressure on every sq.in. of surface, is self-adjusting, and can take care of a reasonable amount of angularity and misalignment. Adhesion is obtained through the friction liners which are riveted to brass plates vulcanized to the clutch gland on both the expanding and contracting types of clutch. Two distinct types of lining are used, a friction lining where loads are to be picked up gradually and where excessive slippage is encountered, and the plain rubber squeegee tread where the slippage is small. Clutches are given special treatment to prevent disintegration by oil fumes. Designed to replace multiple-disk and other plate clutches in various installations, a complete line of Airflex clutches is now being developed for industrial purposes. Thomas L. Fawick Co., Akron, Ohio.

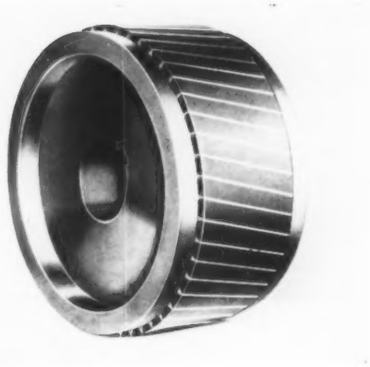


Furnace Controller

Designed to balance the heating rate of furnaces, ovens, and heaters, to meet varying heat requirements, the Rheotrol is a simple, easily-adjusted input controller which substitutes rotating cam-operated switches for power consuming resistors, thereby effecting a considerable reduction in power consumption. Stepless "on-off" control of heating rate is effected once every minute interval. Available with a contact load capacity of 10 amp. or 35 amp. in a non-inductive 110 v. a.c. circuit. Wheelco Instruments Co., 1929–1933 S. Halsted St., Chicago, Ill.

Copperspun Rotor

A new squirrel cage motor rotor, centrifugally cast in one piece of copper, combines the good electrical properties of copper with the indestructibility of a one-piece rotor winding. The rotor, after the centrifugal casting operation, is accurately machined, and is dynamically balanced to a high degree of accuracy after assembly. The use of copper, made possible for the first time in one-piece rotor windings, permits higher running temperatures. Specially designed fans have been developed for this new rotor. Fairbanks, Morse & Co., 600 S. Michigan, Chicago, Ill.



Wrinkle Finish

A new resin for wrinkling varnishes offers particular advantages in allowing an appreciable length of time to elapse between the spraying and the baking operations. Also, with a proper selection of the phenol gum used, the time of baking can be shortened materially to still give an extremely hard, tough wrinkle finish. The resin belongs in the class of a phenol modified, oil extended alkyd, but is a revolutionary departure from the usual method used in the manufacture of such a gum. New Wrinkle, Inc., Dayton, Ohio.

Collision Switch

In addition to operating when tip-over occurs, this new type of collision switch also opens the ignition circuit in cases of collision when tip-over does not occur. The switch features a weight held in place in a contact cup by spring tension. When collision or tip-over occurs, the impact forces the weight out of the cup recess, breaking the circuit. Silver plated contacts prevent loss in ignition circuits and

the switch has no breakable parts. Resetting is accomplished by lifting the knob in the top of the cover and replacing the weight in the cup recess. Available for battery or magneto type ignition. Elsbert Mfg. Co., Inc., 353 West Grand Ave., Chicago, Ill.

Motor Reducer

Known as the Planetorque Motoreducer, this new motor drive provides protection for any equipment that might jam or become overloaded, by shutting off

the motor automatically and instantly when the load exceeds a predetermined value. Whenever excessive torque is imposed on the output shaft, a heavy spring which normally holds the internal gear in position is deflected. This spring movement actuates the switch, disconnecting the power. Planetorque Motoreducer can be supplied for horizontal or vertical drive in all horsepowers and ratios for industrial use. Furnished for clockwise or counter-clockwise rotation, or for both if reversing service is desired. Philadelphia Gear Works, Venango and "G" Sts., Philadelphia, Pa.

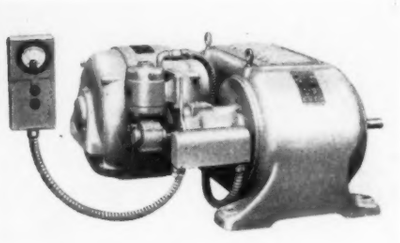
Aircraft Motors

Designed to meet the exacting requirements of aircraft construction, the Type EL-Y Aircraft Motor is also serviceable in the automotive and nautical field, and wherever a low voltage light weight unit is required. Weighing only 3 lb., it features a sturdy housing, and operates at 12 or 24 v. All screws are safety-wired to withstand vibration. Gearing is of the

spur type. It can be wound for 115 volts where an in-line drive is required. Available from 1/20 to 1/16 hp., and in speeds of from 200 to 1200 r.p.m. Dumore Co., Racine, Wis.

Speed Indicator

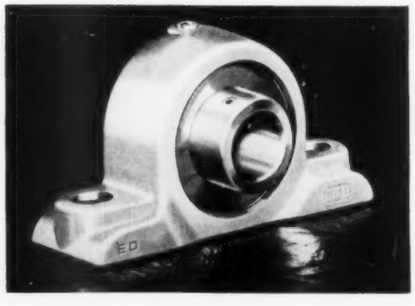
Providing an accurate and simple means of selecting from a remote point the operating speed of the U. S. Varidrive motor, this device consists of a simply constructed indicator meter, mounted in a compact box. Assembly of the indicator and push-button control in the same unit facilitates speed adjustment, since by pushing the high or low button the speed is immediately changed and this change registers on the indicator. The indicator is calibrated in divisions from 1 to 10.



Scales calibrated to customer's requirements are also obtainable. Automatic control equipment may be used. U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles, Cal.

Pillow Block

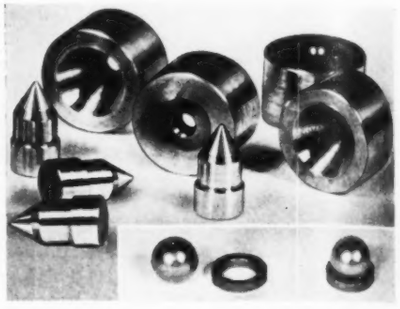
Series "D" light duty ball bearing pillow block consists of a specially designed Ahlberg single-row bearing in a sturdy and neat die-cast housing. The ball bearing is assembled to provide for shaft deflection and misalignment up to



1 deg. Oilproof Neoprene seals are of a floating construction which eliminates friction and increases the life of both seal and bearing. Standard shaft sizes are ½ in., ⅝-in., ¾-in., 1⅛-in., 1 in., 1⅛ in. and 1⅜ in. Ahlberg Bearing Co., Chicago, Ill.

Pump Valves

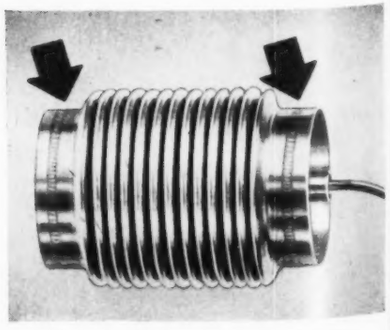
Pump valves and other valves subject to unusual abrasive or corrosive action are now being made of Kennametal, a new intermetallic compound of tungsten-



titanium carbide. In experiments involving a tarry fluid containing grit, Kennametal-tipped valves and seats required only one replacement every one to two weeks, whereas it had previously been necessary to change as many as seven valves in 24 hours. Other tests indicate a superior strength of Kennametal balls and seats for oilwell pump valves. The alloy can be supplied in any desired shape for valve parts and in three grades having varying physical properties. McKenna Metals Co., 178 Lloyd Ave., Latrobe, Pa.

Circular Seam Welding

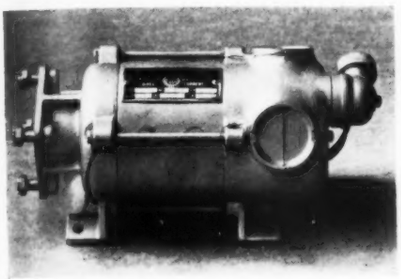
Designed for use in attaching metal end fittings and seals to metallic tubing by resistance welding, this development permits the fabrication of completely sealed vacuum tight units free from soldered, brazed or torch welded joints of any kind. Electric resistance welding can be used in this method in conditions where exceptionally high temperatures and actively corrosive elements preclude even the use of silver solder. Circumference seam welding, made possible through the development of specialized equipment, operates automatically and eliminates entirely the human element present in other welding or soldering procedures. Extremely thin gages of metal



can be handled with ease, and metals of unlike thicknesses or unlike analyses can also be joined. Chicago Metal Hose Corp., 311 South 3rd Ave., Maywood, Ill.

Explosion-Proof Motor

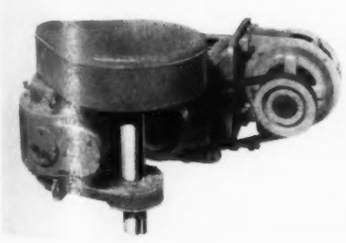
Totally inclosed and explosion-proof, this lightweight motor has an efficiency of 63 per cent. Designed for reliability and long service under continuous operation at full load and severe conditions of vibration, the motor is particularly suited



for use on airplanes. Convenient access is provided to the brushes and commutator by means of special round inspection hole covers, easily removed. Flange mountings and splined shafts are designed to fit standard airplane fuel pumps. Furnished for either 12 or 24 volts, d.c., as specified. Other sizes and types of explosion-proof motors for airplanes and other requirements are also supplied. Electric Specialty Co., Stamford, Conn.

Variable Drive Unit

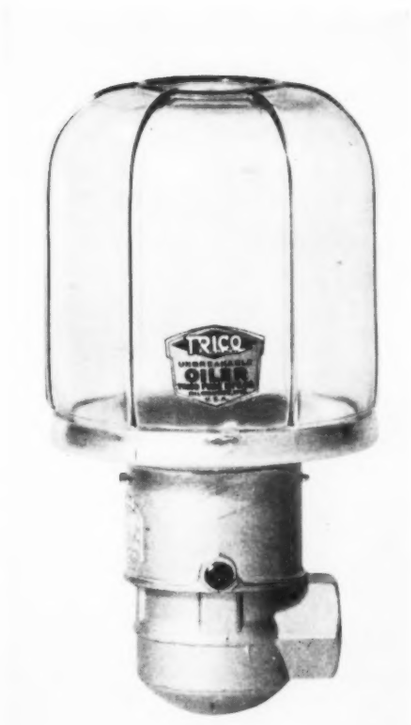
With capacities up to 80,000 in. lb. torque and infinitely variable speed ranges of from 310 r.p.m. forward to 9 r.p.m. reverse, this new compact, self-contained unit of predetermined operating performance and flexible application,



can be used with any standard 1- to 10-hp. motor. Two basic units, identical in design except for capacity, are available. In the larger capacities, the output shaft is vertical and may be had in either upward or downward types. The wide range of speed, controlled by a handle mounted on the side of the drive unit case, is achieved by the combined use of a standard variable-speed, motor-driven transmission and a conventional speed-reducer gearing. Gears run in a bath of oil. A speed indicator is mounted on the side of the case near the speed control handle. Remote control also available. Mechanical Handling Systems, Inc., 4700 Nancy Ave., Detroit, Mich.

Unbreakable Oiler

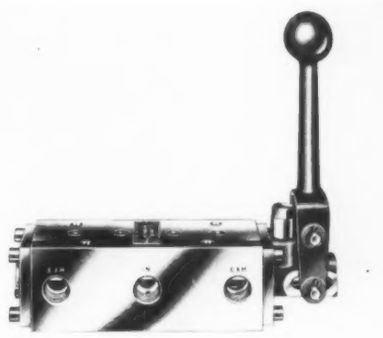
Automatically maintaining the proper oil level in ring or ball bearings and in gear and pump housings, this new line of



visible automatic constant level oilers has unbreakable reservoirs and adjustable oil level. The reinforcing ribs of the reservoir add strength, give streamlined appearance and are easy to grip with the hands. The reservoir is attached to the lower casting by a threaded spout, and is easily removable for convenient cleaning and refilling. Made in 1, 2, 4, and 8 oz. capacities with all bottles interchangeable. Trico Fuse Mfg. Co., Milwaukee, Wis.

Hydraulic Valve

This new single plunger valve for air or hydraulic lines has only one moving part. Speed control of the piston is obtained independently in either direction by individual exhaust outlets at each end of the double acting cylinder. With outlets and inlets in the sides, it can be serviced on the job without dismounting. Construction is sturdy. Since there is no metal-to-metal contact there is no lubri-



cation problem. Made in 25 styles of valve control, in sizes from $\frac{1}{8}$ in. to $1\frac{1}{2}$ in., inclusive. C. B. Hunt & Son, 1915 E. State St., Salem, Ohio.

Non-Metallic Bearings

Molded under high pressure to produce a bearing surface that approaches the hardness of steel, but that cannot score journals, these improved non-metallic bearings contain a patented material known as Gatke Tuftex. The dense, resilient structure withstands pressures and shocks that reduce the life of metallic bearings. Designed for water-lubricated,

oil-lubricated, or grease-lubricated applications, these bearings are also available in self-lubricated types. Gatke Corp., 226 N. La Salle St., Chicago, Ill.

Manufacturers' Publications

AMMETER—Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark, N. J. Bulletin A-2-B, 4 pages, 8½ x 11 in. The Weston Clamp-Ammeter is fully described in this publication, which illustrates, lists the ranges for, and gives applications of this instrument.

ANCHORAGES—The Rawlplug Co., Inc., 98 Lafayette St., New York, N. Y. Catalog 39, 38 pages, 3½x6¼ in. This profusely illustrated handbook has many tables and charts and other valuable data pertaining to the anchorage of bolts and screws in concrete.

BEARINGS—Bound Brook Oil-Less Bearing Co., Bound Brook, N. J. Supplement 3-1-39, 14 pages, 8½ x 11 in. This supplement contains a die-list which completes the reference data on "Compo" oil-retaining porous bronze bearings. Complete dimensions of sizes available are given.

BEARINGS—Gwilliam Co., 360 Furman St., Brooklyn, N. Y. Catalog No. 16, 16 pages, 8½ x 11 in. The complete line of Gwilliam ball and roller bearings is set forth in this catalog, which contains illustrations of the various types available. Dimension tables of the standard sizes are also included.

BEARINGS—Hyatt Bearings Div., General Motors Sales Corp., Harrison, N. J. Catalog, 48 pages, 9x11¼ in. The Hyatt roller bearing journal box, its description, manufacture and advantages are discussed in this well-illustrated catalog, which covers all types of Hyatt railroad bearing equipment.

BELTING AND PACKING—E. F. Houghton & Co., Third, American and Somerset Sts., Philadelphia, Pa. "Research, Illustrated," 20 pages, 8½ x 11 in. This recent edition of the Houghton publication is devoted to leather belting and packing, and contains several well illustrated articles concerning these items.

CARBOLOY—Carboloy Co. Inc., Detroit, Mich. Bulletin GT-114, 8 pages, 8½ x 11 in. This booklet contains much tabulated engineering data giving detailed recommendations for cemented carbide tools, suggested speeds and feeds, and a method for determining power requirements. Bulletin GT-115, a companion publication, lists physical characteristics and general use of carboloy grades.

CERAMICS—American Lava Corp., Chattanooga, Tenn. Bulletin 39. This new catalog gives more complete information, both in text and pictures, than ever offered previously on Steatite ceramics.

DECIMAL EQUIVALENT—Frederick Post Co., Box 803, Chicago, Ill. A handy method for placing the decimal equivalent chart close at hand in drafting, this decimal equivalent chart, 7¼ x 11½ in., is a decalcomania transfer which can be applied directly to a T-square.

FLEXIBLE COUPLINGS—Morse Chain Co., Ithaca, N. Y. Bulletin 57, 32 pages, 8½ x 11 in. This new catalog contains complete engineering data, installation and operating information, and recommended applications for the entire Morse flexible coupling line. The booklet is well illustrated with photographs and dimension drawings.

FORGINGS—American Forge Div., American Brake Shoe & Foundry Co., 2621 South Hoyne Ave., Chicago, Ill. "Judge Amforge Holds a Radio Quiz," 16 pages, 5¼ x 7¼ in. This booklet presents in an unusual way many interesting facts about Upset forgings. The application of Upset forgings in many fields is discussed.

GAS WELDER—Department 7-N-20, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. "Tips on Building Your Own Gas-Engine Welder," 12 pages, 5¼ x 7¾ in. This booklet is addressed to shops desiring to build their own portable gas-engine welder units. It discusses construction materials, and includes suggestions and tables of minimum engine sizes for given generator ratings, as well as electrode sizes and welding ranges.

LOOM MOTORS—Department 7-N-20, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Bulletin F-8484, 4 pages, 8½ x 11 in. Totally inclosed loom motors of ½ to 2 hp. are described in this new booklet. These motors are for 220-, 440-, or 550-volt power supply, 60 cycles, two- and three-phase.

MANGANESE STEEL—American Manganese Steel Div., Chicago Heights, Ill. "Amsco Manganese Steel, The Toughest Steel Known," 64 pages, 8½ x 11 in. Covering the origin, physical properties, and reasons for its resistance to impact and abrasion, this well illustrated catalog includes many pages illustrating uses for manganese steel castings in industries using equipment which are exposed to impact and abrasion.

MOTOR STARTER—General Electric Co., Schenectady, N. Y. Bulletin GEA-2964A, 6 pages, 8½ x 11 in. This folder illustrates and describes the new full voltage magnetic motor starter listed as CR7006-D51. The several available forms of this starter are described, with dimensions.

PLASTICS—E. I. du Pont de Nemours & Co., Inc., 626 Schuyler Ave., Arlington, N. J. "Du Pont Plastics Bulletin," 4 pages, 8½ x 11 in. This new publication, to be published regularly, is designed to present news of latest developments and applications of plastics. Successive issues of the bulletin will increase the accumulation of helpful data important to users of plastics.

PYROMETERS—Foxboro Co., Foxboro, Mass. Bulletin 773, 4 pages, 8½x11 in. Many types of Foxboro pyrometers and resistance thermometers are illustrated and described in this folder, which covers the most familiar instruments in the Foxboro line.

ROTARY CONVERTER—Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill. Bulletin 13-1, 4 pages, 8½ x 11 in. Dimensions, wiring diagrams and the performance characteristics of rotary converters for converting direct current to alternating current for use with radios, public address systems, X-ray machines and similar equipment, are included in this folder.

SOLENOID VALVE—Hoppe Engineering Co., Indianapolis, Ind. Bulletin D2, 2 pages, 8½ x 11 in. The Type D solenoid valve for use in fluid lines is illustrated and described in this bulletin, which also lists the prices and dimensions.

SPEED REDUCERS—Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill. Bulletin 22-11, 3½ x 6¼ in. The various types of Janette motorized speed reducers, of which there are 19 available in 43 different sizes, are illustrated and described in this folder.

STEEL—LaSalle Steel Co., Chicago, Ill. Booklet 50, 8 pages, 8½ x 11 in. Stressproof No. 1 and 2 steels, their application in bolts, studs, spindles, shafts, pins, and gears, are discussed in this well illustrated book.

STEEL—Joseph T. Ryerson & Son, Inc., 16th and Rockwell Sts., Chicago, Ill. Catalog No. 2, 240 pages, 5 x 8½ in. The new products and sizes recently added to the Ryerson stock of certified steels are included in this detailed stock list. Weights, lengths, cutting data and other pertinent information are given. The catalog is thumb-tabbed for quick reference.

TEMPERATURE DETECTOR—Leeds & Northrup Co., 4911 Stenton Ave., Philadelphia, Pa. Folder N33B(2), 6 pages, 7¾ x 10½ in. A description of Rayotube and pictures showing some of its uses in heat-treat, forge-shop, steel mills, cement and lime plants, and factories, are contained in this well illustrated booklet.

THERMOGUARD—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Booklet F-8490, 4 pages, 8½ x 11 in. Thermoguard, a device which makes a motor completely self-protective, is described in this well illustrated folder, which sets forth the three types available to meet every need.

TRANSFORMERS—Allis-Chalmers Mfg. Co., Milwaukee, Wis. Bulletin B6007, 2 pages, 8½ x 11 in. This bulletin describes small auto transformers for serving electric tools, appliances and lights requiring 120 v. from a 240 v. supply line.

V-BELTS—Manhattan Rubber Mfg. Div., Passaic, N. J. Engineering data book, third edition, 60 pages, 8½ x 11 in. The first part of this catalog covers standard drives eliminating the necessity of working out calculations, and the second part gives sheave factors for designing new or special drives. It also contains belt comparison tables and other general information.

VARI-SPEED CONTROLS—Columbia Vari-Speed Co., Wheaton, Ill. Catalog JFS-Jr., 8 pages, 8½ x 11 in. The Columbia JFS-Jr. vari-speed control is described in this catalog, which includes much useful engineering data. Typical applications are also illustrated.

WORM GEARS—De Laval Steam Turbine Co., Trenton, N. J. Leaflet E-1175, 16 pages, 8½x11 in. This publication presents briefly the advantages of worm gears in transmitting power, and contains many pages of illustrations of applications of worm gears in industry.

WRINKLE FINISH—New Wrinkles, Inc., Mutual Home Bldg., Dayton, Ohio. "New Wrinkles in Finishing," 8 pages, 8½ x 11 in. Several articles covering wrinkle finishes and their application are contained in this booklet, which is a periodical publication.

Helical Spring Tables—I

PAUL KLAMP

WHEREAS gears and worm gears, chain drives, belt and V-belt drives, ball and roller bearings, can be selected from catalogs, tables or charts, helical springs are so varied in size and design that it is out of the question to catalog a sufficient number of springs to take care of the majority of requirements. Long, tedious calculations are generally necessary.

While it is quite in order to devote considerable time to the design of a spring which is to be made in large quantities, the untold number of hours spent on the calculation of springs produced in small lots could be used to much better advantage if it were possible to just "look up" a spring.

This cannot be done with present tables or charts. Let us consider, for instance, the design of a spring with reciprocating motion and with a given load at the maximum working length and a specified working stroke or range. After making a tentative selection of a certain O.D. and wire size which yields the spring load and deflection per coil at a nominal stress value, it is necessary to carry the calculation through, at least roughly, in order to find out what the working length and free length will be, and whether the load increase during the working stroke is of reasonable proportions, or whether the stress range is not too large in relation to the maximum stress. Usually the first selection is not satisfactory, so that the procedure must be repeated until all requirements are met. The calculation is especially cumbersome, if the spring has to fit into either a limited or a definite space, or when it is necessary to use two springs, one inside the other.

The method described here does away with the cut-and-try process of spring calculation by providing a direct and systematic approach, with the aid of new spring tables which eliminate calculations almost entirely. Of further help are six spring selection forms to follow in later numbers of *Product Engineering* which outline the procedure of selecting compression springs of various types.

Because of the large amount of space required to fully present this method, complete with tables, outline of procedure for selecting various types of helical compression springs, methods of calculating the tables, and general considerations, it will be necessary to continue this article over a period of a few months.

Investigations of the physical properties of various grades of spring steel have shown that wire of small size can safely be subjected to much higher torsional stresses than heavy wire. Furthermore, the maximum allowable stresses for a spring under static load will not be safe for a spring which is reciprocated rapidly. For this reason, the stresses used in spring calculations should vary according to wire size and operating conditions. Therefore, in table B the safe load and deflection per coil for each listed combination of outside diameter and wire size have been computed for three different stresses, a low, medium and high value, and these three values range higher for small wire diameters, lower for medium wire sizes, and still lower for heavy wire. In addition to the operating conditions, there are other factors upon which the choice of the stress group depends.

Selection of Stress Group

In Table A a guide is presented from which the proper stress group can be selected. In this table are shown a number of spring wire materials, as well as the stress groups recommended for the various materials and for different types of loading and different load increase factors i. Since the stresses used in Table B are limited to three values for each wire size, the stresses according to Table A compare only approximately with modern stress recommendations and are usually somewhat on the conservative side. But for the general run of springs, the choice of stresses is quite sufficient.

The load increase factor i referred to in Table A is equal to

$$i = \frac{\textit{load at minimum working length}}{\textit{load at maximum working length}}$$

Its choice depends on the requirements of the mechanism of which the spring is a part. Usually the load at the maximum working length is the basic load, and a large load increase during the working stroke is not desirable. But the smaller the load increase factor, the larger will be the required spring. Good average values for i are 1.33 to 1.50. However, if the spring has to provide a larger accelerating force in the first part of the expanding stroke, a large value for i is in order.

A list of the stresses used in table B is given here. They were chosen after a survey of the available literature and of leading spring manufacturers' recommendations and are principally intended for the general run of springs, such as are used in machine tools, fixtures, general machinery, testing apparatus, shop equipment and so forth. For springs made in large volume, somewhat higher stresses are used sometimes, but the design of such springs often involves extensive research and testing for surge and fatigue and frequently calls for special spring steel.

Calculation of Table B

The safe loads and deflections per coil on Table B were obtained from the generally accepted formulas:

$$P = \frac{\pi d^3 S}{16rk} \qquad (1)$$

and

$$f = \frac{64 P r^3}{G d^4} \qquad (2)$$

where

P = safe load in lb.
d = wire diameter in in.
S = torsional stress in lb. per sq.in.
r = mean radius of coils in in.
f = deflection per coil in in.
G = torsional modulus

while k is a correction factor developed by Dr. A. M. Wahl of the Westinghouse Electric & Manufacturing Company.

$$k = \frac{4c - 1}{4c - 4} + \frac{0.615}{c}$$

where

$$c = \frac{2r}{d}$$

A torsional modulus of 11,500,000 was used in these calculations. Hot rolled wire over ½ in. diameter and stainless steel have a lower modulus, so that a modification of the load P is required.

Since the deflections per coil on Table

B are used with little or no change when selecting a spring according to directions, it was possible to establish the lead of the coils and include it in the table, as follows:

$$L = d + f + C$$

where

L = lead of coils in in.
d = wire diameter
f = deflection per coil
C = clearance between coils at load P

It is customary to make C approximately 10 per cent of the wire diameter. While this amount is suitable for many springs, it is not sufficient for springs having a large index $2r/d$. In such a case, f is often five times as large as d, so that with $C = 1/10\ d$, C will be $1/50\ f$. This means that a spring with a total deflection of 1 in., for instance, would close up solid after 0.02 in. of additional motion, or if the solid length were 0.02 in. over the normal size, or if accumulated errors in the mechanism of which the spring is a member would add up to 0.02 in. Evidently such a coil clearance is too small. For this reason the values C, used to find the table values L, normally were made to equal 10 per cent of the larger of the two values d and f.

The values for L thus found were rounded off slightly for springs having a wire diameter larger than $\frac{1}{4}$ in., but for wire sizes of $\frac{1}{4}$ in. and smaller they were modified so as to obtain a number of coils per in., $n = 1/L$, that is obtainable on spring winding machines as well as on standard lathes.

Another feature of Table B is that for every listed O.D. and wire size, the inside diameter (I.D.) is given. This is an aid in selecting a spring to fit around a pin, plunger, or shaft.

The wire diameters on Table B correspond to the Washburn & Moen gages which are in general use for round spring steel wire. Since various number gages are in use for other materials, it is best to give the size in decimals. Also included are some generally-used fractional sizes.

Ratio of the Spring

Next, spring Table B shows a value R for every spring in each stress group. This value is referred to as the ratio of the spring, because it expresses the ratio between the active free length and the total deflection. It has other uses. The value $R-1$, for instance, is the ratio between the minimum working length and the total deflection, as shown below. Again, it saves much time when selecting a spring which is to have a specified scale per in. or load rate. The definite relation between the ratio, deflection per coil and lead of coils, is in the following:

Let

l_o = active free length
D = total deflection
N = number of active coils
f = deflection per coil
L = lead of coils
R = ratio of spring

then we have, by definition

$$R = \frac{l_o}{D} \tag{3}$$

but $l_o = NL$ and $D = Nf$
so that

$$R = \frac{L}{f} \tag{4}$$

When the number of coils per in. n is given, where $L = \frac{1}{n}$, Equation (4) will change to

$$R = \frac{1}{nf} \tag{5}$$

Equations (4) and (5) were used to compute the table values R. When R is computed from the table values f and L or n, the figure obtained may differ slightly from the table value R because an additional decimal place was used in the values from which R was calculated.

Stresses Used in Computing Table B

Wire Diameter	Stress Groups — Low	Medium	High
Up to $\frac{3}{32}$ in.	60,000	75,000	90,000
0.1055 in. to 0.2253 in.	55,000	67,500	81,000
0.2437 in. to $\frac{5}{8}$ in.	50,000	60,000	72,000

Furthermore, with

l_m = active minimum working length,

we have

$l_o - D = l_m$

The value for l_o, according to Equation (3), is

$l_o = DR$ (6)

By substituting this value in the formula above, we get

$$RD - D = l_m$$

and, solving for D

$$D = \frac{l_m}{R-1} \tag{7}$$

Thus, with the total deflection D predetermined, the active free length l_o of the spring can be found according to Equation (6), immediately after a spring is picked from Table B which shows the value R, in addition to the O.D. size, wire size, load and coils per in. It may be noted that by finding the O.D. and active free length simultaneously, it is now possible to select the most suitable proportions of the spring at the first attempt.

In case a spring with reciprocating motion has to have a specified minimum working length, the total deflection and thus the free length can be predetermined as shown before, so that now R is found from Equation (3) and will serve as a key for selecting a spring (from Table B) that will fit into the given space. (Compare spring selection forms Nos. 4 and 5).

When the outside diameter of a spring is specified, the choice of table loads is limited, so that occasionally the difference between the required load and the next higher table load is too great. In such a case, the table load can be reduced to the exact value desired, if the table ratio R is modified accordingly and then used in the usual manner.

Let P = table load
P_1 = required load
R = table ratio
R_1 = modified ratio
f = deflection per coil at P
f_1 = deflection per coil at P_1
L = lead of coils

Then we have from Equation (4)

$$R = \frac{L}{f} \text{ and } R_1 = \frac{L}{f_1}$$

Multiplying both sides of these equations by P and P_1 respectively, we get

$$RP = \frac{P}{f} L \text{ and } R_1 P_1 = \frac{P_1}{f_1} L$$

The right sides of both equations are equal, so that the left sides must also be equal. Thus

$$R_1 P_1 = RP \tag{8}$$

And, solving for R_1

$$R_1 = R \frac{P}{P_1} \tag{9}$$

According to Equation (8), the table values R and P may be changed as long as the new values R_1 and P_1 when multiplied by each other, will produce the same answer as obtained when multiplying the table values R and P by each other. However, P_1 should not exceed P and, therefore, R_1 should not be smaller than R, so as to maintain proper coil clearance. Since RP is constant for a given spring, this product may be called the load constant. It is used in several spring calculations and could have been

computed for each spring and given in Table B. These constants were omitted, to keep this table from becoming too crowded.

Equation (9) shows how to obtain the modified ratio R_1 when table load P is reduced to P_1.

When a spring has to have a definite scale per in. or rate of load, the ratio R again serves to simplify the spring design. Below a formula is developed which applies to such cases.

Let P_1 = required maximum load
P = table load
R = table ratio
R_1 = ratio at required load P
l_0 = active free length
D = total deflection
p = required scale per in.

Now we have, by definition

$$p = \frac{P_1}{D} \qquad (10)$$

So that

$$D = \frac{P_1}{p} \qquad (11)$$

According to Equation (3), we have

$$D = \frac{l_0}{R_1}$$

Inserting this value for D in Equation (10) and solving for l_0, we get

$$l_0 = \frac{P_1 R_1}{p}$$

But, from Equation (8), $P_1 R_1 = P R$, so that

$$l_0 = \frac{PR}{p} \qquad (12)$$

Now the total deflection D can be obtained from Equation (11) and the active free length from Equation (12). Note that R_1 drops out and is not used in the selection of a spring which has a definite scale per in.

When the required O.D. is not listed in Table B, use the following method to find P, R and number of coils per in. or lead of coils.

1. Interpolate P and f from the springs of the same wire diameter and of the next lower and higher O.D. sizes. Note that P decreases and f increases as the O.D. gets larger.

2. Find lead L of the coils as follows:

$$L = f + d + C$$

making C equal to 10 per cent of the larger of the two values, f and d. When required, find the number of coils per in. n from the lead L as follows:

$$n = \frac{1}{L}$$

and round off n to the next lower of these values used in Table B. Rounding off to the next higher value is permissible if, in checking back, C is found not to be less than 7½ per cent of the larger of the two values f and d.

3. Find R from f and n by the first formula below and, if n is not used, from f and L by the second formula.

$$R = \frac{1}{nf} \text{ or } R = \frac{L}{f}$$

Occasionally a spring requires a very light load and, at the same time, a large O.D. In this case, the table load of any spring in this O.D. group will be too high. Therefore, reduce the table load and find the modified ratio. When the space available for the working length is limited, the load of the coils may be reduced, since the deflection per coil f is now smaller. The smaller load and the new value R is then found as in the previous paragraph, after f has been reduced in the same proportion as the load P.

(Continued on next page)

Table A—Stress Groups for Helical Springs

Material	Wire Diameter	Infrequent Applications or Static Load	Rapid Reciprocating Motion with Variable Working Stroke So That Max. Load Is Approached Only Occasionally. Also Slow Reciprocation		Rapid Reciprocation					
			Load Increase Factor, i		Load Increase Factor, i					
			Up To 1.5	Over 1.5	Up To 1.33	1.4	1.5	1.667	1.8	2
Music wire	Small sizes	High	High	High	High	High	High	High	High	High
Carbon steel pretempered	Medium sizes	High	Medium	Low	Medium	Medium	Medium	Low	Low	Low
Hot rolled steel quenched and tempered after coiling	Larger sizes	Medium	Medium	Low	Medium	Low	Low	Low	.....	.....
Carbon steel hard drawn	Medium sizes	Low	Low	.....	Low	.....	.....	.....	.....	.....
Special high grade valve spring wire pretempered	Medium sizes	.....	High	High	High	High	High	High	High	High
Stainless steel	Medium & larger sizes	Low	Low	.....	Low	.....	.....	.....	.....	.....
Chrome vanadium steel wire quenched and tempered after coiling	Medium & larger sizes	High	High	High	High	High	High	Medium	Medium	Medium

Table B—Selection of Springs

Spring O. D. In.	Wire Dia. In.	Spring I. D. In.	Low Stress Group				Medium Stress Group				High Stress Group			
			Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.
3/16	.014	.160	18	.334	1.76	.0316	16	.417	1.58	.0395	14	.501	1.51	.0474
	.0162	.155	20	.515	1.91	.0261	18	.644	1.70	.0327	16	.772	1.59	.0392
	.0181	.151	22	.711	2.02	.0225	18	.892	1.98	.0281	16	1.07	1.85	.0337
	.0204	.147	22	1.02	2.39	.0190	20	1.27	2.10	.0238	18	1.52	1.95	.0285
	.023	.142	22	1.44	2.85	.0160	20	1.80	2.51	.0200	18	2.16	2.32	.0240
	.0258	.136	22	2.02	3.39	.0134	20	2.52	2.99	.0168	18	3.03	2.77	.0201
	.0286	.130	22	2.72	4.01	.0113	20	3.40	3.53	.0142	18	4.08	3.27	.0170
	.03175	.124	20	3.68	5.26	.0095	20	4.60	4.21	.0119	18	5.52	3.90	.0143
	.0348	.118	20	4.78	6.20	.0081	20	5.97	4.96	.0101	18	7.17	4.59	.0121
1/4	.0162	.218	13	.390	1.53	.0501	11	.488	1.44	.0629	10	.585	1.32	.0755
	.0181	.211	14	.542	1.63	.0438	12	.678	1.52	.0548	11	.813	1.38	.0657
	.0204	.209	14	.773	1.90	.0376	13	.966	1.64	.0470	12	1.16	1.48	.0563
	.023	.201	16	1.10	1.95	.0320	14	1.38	1.79	.0400	13	1.65	1.60	.0480
	.0258	.198	16	1.54	2.29	.0273	14	1.93	2.09	.0342	13	2.32	1.88	.0410
	.0286	.193	16	2.09	2.65	.0236	14	2.61	2.42	.0295	14	3.14	2.02	.0354
	.03175	.187	16	2.84	3.09	.0202	16	3.55	2.18	.0253	14	4.26	2.36	.0303
	.0348	.180	16	3.71	3.56	.0175	16	4.64	2.85	.0219	14	5.56	2.72	.0263
	.041	.168	16	5.96	4.67	.0131	16	7.45	3.73	.0167	14	8.91	3.56	.0201
	.0475	.155	16	9.07	6.07	.0103	14	11.3	5.55	.0129	14	13.6	4.63	.0155
5/16	.0204	.272	11	.623	1.46	.0621	9	.779	1.43	.0780	8	.934	1.34	.0935
	.023	.267	12	.889	1.55	.0536	10	1.11	1.49	.0670	9	1.33	1.38	.0805
	.0258	.261	12	1.25	1.80	.0462	11	1.56	1.57	.0578	9	1.87	1.60	.0694
	.0286	.255	13	1.69	1.91	.0403	11	2.12	1.80	.0504	10	2.54	1.65	.0605
	.03175	.249	13	2.31	2.20	.0349	12	2.88	1.91	.0437	11	3.46	1.74	.0524
	.0348	.243	14	3.02	2.33	.0307	12	3.77	2.17	.0383	11	4.53	1.98	.0460
	.041	.231	14	4.88	2.97	.0240	13	6.10	2.56	.0300	12	7.32	2.31	.0360
	.0475	.217	14	7.48	3.76	.0190	13	9.35	3.24	.0238	12	11.2	2.92	.0285
	.054	.205	13	10.8	5.03	.0153	12	13.5	4.36	.0191	12	16.2	3.63	.0229
	.0625	.188	12	16.4	7.14	.0117	12	20.5	5.71	.0146	11	24.6	5.19	.0175
3/8	.023	.329	9	.746	1.37	.0809	7	.932	1.41	.101	6	1.12	1.37	.121
	.0258	.323	9	1.05	1.59	.0701	8	1.31	1.43	.0876	7	1.57	1.36	.105
	.0286	.318	10	1.42	1.63	.0615	8	1.78	1.63	.0769	7	2.14	1.55	.0923
	.03175	.312	11	1.94	1.69	.0537	9	2.42	1.66	.0671	8	2.91	1.55	.0805
	.0348	.305	11	2.55	1.91	.0476	10	3.19	1.68	.0595	8	3.82	1.75	.0714
	.041	.293	11	4.12	2.11	.0378	10	5.15	2.12	.0472	9	6.18	1.96	.0567
	.0475	.280	12	6.34	2.74	.0301	11	7.93	2.39	.0380	10	9.51	2.19	.0457
	.054	.267	11	9.21	3.65	.0219	11	11.5	2.92	.0311	10	13.8	2.68	.0374
	.0625	.250	11	14.0	4.65	.0195	10	17.6	4.10	.0244	10	21.1	3.41	.0293
	.072	.231	10	21.0	6.60	.0151	10	26.3	5.28	.0189	10	31.6	4.40	.0227
7/16	.0286	.380	8	1.23	1.43	.0872	6	1.53	1.53	.109	5½	1.84	1.39	.131
	.03175	.374	8	1.67	1.64	.0764	7	2.09	1.50	.0955	6	2.51	1.45	.115
	.0348	.368	9	2.19	1.64	.0680	7	2.74	1.68	.0819	6	3.29	1.64	.102
	.041	.356	9	3.56	2.03	.0547	8	4.45	1.83	.0683	7	5.34	1.74	.0820
	.0475	.343	10	5.49	2.25	.0445	9	6.87	2.00	.0557	8	8.24	1.87	.0668
	.054	.330	10	8.00	2.71	.0369	9	9.99	2.41	.0461	8	12.0	2.26	.0553
	.0625	.313	10	12.2	3.40	.0294	9	15.3	3.02	.0368	8	18.4	2.83	.0442
	.072	.291	9	18.4	4.77	.0233	9	23.1	3.81	.0291	8	27.7	3.58	.0350
	.080	.278	9	24.9	5.75	.0193	8	31.2	5.17	.0242	8	37.4	4.31	.0290
	.0915	.255	8	36.4	8.35	.0150	8	45.5	6.68	.0187	8	54.6	5.57	.0225
1/2	.03175	.437	7	1.47	1.38	.103	5½	1.84	1.41	.129	5	2.20	1.29	.155
	.0348	.430	7	1.93	1.55	.0921	6	2.41	1.45	.115	5	2.89	1.45	.138
	.041	.418	8	3.13	1.68	.0746	7	3.92	1.53	.0933	6	4.70	1.49	.112
	.0475	.405	8	4.84	2.01	.0613	7	6.05	1.86	.0766	6	7.26	1.81	.0920
	.054	.392	9	7.07	2.17	.0514	8	8.83	1.95	.0641	7	10.6	1.86	.0769
	.0625	.375	9	10.8	2.68	.0411	8	13.6	2.42	.0517	7	16.3	2.30	.0621
	.072	.356	9	16.4	3.34	.0332	8	20.5	3.01	.0415	7	24.6	2.87	.0498
	.080	.340	8	22.2	4.47	.0280	8	27.7	3.58	.0349	7	33.3	3.41	.0419
	.0915	.317	8	32.6	5.66	.0221	7	40.8	5.17	.0276	7	49.0	4.31	.0332
	3/32	.313	8	35.0	5.92	.0211	7	43.7	5.42	.0264	7	52.4	4.51	.0317